An investigation into land-use change in two contrasting areas in the Nile Delta, Egypt

by

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Abstract

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Understanding land-use change in developing countries, particularly those situated in environmentally vulnerable arid and semi-arid zones, is crucial given the considerable pressures arising due to rapid population growth, climate change and desertification. The purpose of this research was to investigate the main drivers affecting land-use change in the eastern part of the Nile Delta, Egypt in the last two decades. Two contrasting cities in the region were selected for detailed analysis. Almansourah is an ancient settlement relatively close to the Damietta branch of the Nile whereas Alzaqazig is a recent development and the surrounding area was reclaimed from the desert.

The DPSIR (driving forces, pressures, state, impacts and responses) model was adopted as the conceptual framework for organising and categorising the factors affecting land-use change in these two areas. It is a linear, 'formulaic' approach, based on the concept of causality chains which connect human activities with environmental information. The case study approach was used as the main methodology, although both qualitative and quantitative techniques were employed throughout. A range of sources were consulted throughout the investigation to ensure that the evidence was internally consistent: remote sensing data, questionnaire data, interviews, participant observation and census data. More than 180 farmers were interviewed in the two study areas and the majority of these (71%) farmed less than 2ha.

Using remote sensing data it was found that crop patterns had changed considerably in the two areas both with regard to their geographical distribution and extent. In the Almansourah study area, the key changes during the past two decades were the increase of cotton area and the decrease in rice, maize and other crops. In contrast, the Alzaqazig study area experienced an increase in cotton and rice area with minor increase in maize fields. There was also an expansion of urban and rural-urban settlements into agricultural land in both the study areas.

One of the critical physical factors for land-use change was found to be the need for irrigation water. Regarding the two study areas, Almansourah currently enjoys greater availability of irrigation water because of its proximity to the Nile compared to Alzaqazig which facilitated land-use change in Almansourah. On a more general level the aridity of the Nile Delta region makes water a limiting factor in agricultural production.

Analysis of the driving forces showed that land-use change was highly dependent on economic factors such as transportation availability and cost as well as the contribution of women. Land-use change was significantly influenced by transportation availability in Almansourah but not in Alzaqazig possibly because of the greater need to transport agricultural produce to market. Social drivers were also found to be significant. One significant pressure was caused by population growth; in Almansourah the lack of alternative sources of land led to the expansion of urban and rural urban settlements onto fertile agricultural fields. The study confirmed that a farmer's educational level plays an important role in agricultural production. Almost 25% of farmers in Almansourah and 30% in Alzaqaziq had no formal education and this difference led to variations in land-use change between the areas. Education level was found to have a considerable influence on crop rotation and manure use in the Almansourah study area. Conversely, subsidies from private financial sources and rural women's contribution to agricultural production were among the key drivers for land-use change in the Alzaqazig study area.

One of the innovative aspects of this study was the application of the DPSIR framework. Although it has been used to advantage in the developed world, it has not been applied to study land-use change in an arid, developing country. The study confirmed that the framework worked well in such a context. Notable strengths included its comprehensive nature, ability to deal with uncertainty and handle different types of data. A further advantage was that it could incorporate sub-models to investigate individual driving forces, for example, the need for irrigation water. Overall the use of DPSIR was flexible enough to highlight the major causative drivers affecting land-use and also to take account of the action of more subtle and complex factors.

Author's Declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Graduate Committee.

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Chapter 1: General introduction

1.1 Background and problem definition

The research question addressed in this thesis focuses on land-use change in the eastern part of the Nile Delta of Egypt. Understanding land-use change is particularly important in arid and semi-arid regions where agricultural land is limited and where food security and agricultural production suffer from many constraints including lack of precipitation, poor quality soils and increasing population growth.

Land-use processes are never static and have always been changing for, as Jongman and Bunce (2000: 27) emphasised, land-use *"has a rhythm that is related to ... political, economic and social changes in society"*. In recent decades, studies of land-use change have become important aspects of research into environmental change, especially since land-use and land-cover change are major elements in climate change, ecosystem processes, biogeochemical cycles, biodiversity preservation, and human-environment interactions in general[1] (Lopez *et al.*, 2001; Aguilar *et al.*, 2003; Xiao *et al.*, 2006).

The importance of understanding drivers for land-use change in arid and semi-arid areas has been highlighted by both Aboelghar *et al.* (2004) and Shalaby and Tateisni (2007)

[1] For this reason, land-use and land-cover change have been treated as a joint theme by the International Geosphere Biosphere Programme (IGBP) and by the International Human Dimensions Programme on Global Environmental Change (IHDP).

and stems particularly from the increasing pressures put on such areas by intensive human-environment interactions. According to the United Nations (1997), about 1.9 billion ha of land worldwide (an area approximately the size of Canada and the USA) is affected by land degradation. Of this, 21 M ha is so degraded each year that crop production will soon no longer be economic and production is likely to cease totally on a further 6 M ha. Furthermore, the livelihoods of over 900 million people living in more than 100 countries are now adversely affected by land degradation. Populations of arid and semi-arid zones in the developing world are the most seriously affected (El-Beltagy, 1999) because their agricultural production is under increasing threat from the combined pressures of desertification, salinisation and population increase (Wilson and Juntti, 2005).

There is considerable interest in investigating the influence of such pressures on land-use change in arid and semi-arid zones (Wood *et al.*, 2004). Although many studies have noted that climatic change factors are playing an increasingly dominant role, human activities are responsible for much of the change (Riebsame *et al.*, 1994; De Koning *et al.*, 1999; Kok *et al.*, 2001). Land-use change research is particularly important in areas undergoing fast, usually unplanned, alteration from agriculture to urban use. These transitional areas are usually situated adjacent to large urban conurbations where the population is growing extremely rapidly (Lopez *et al.*, 2001). In the past decade much attention has been paid to understanding rural-urban land-use change because vast numbers of the world's population are affected (see for example Tan *et al.*, 2005; Yin *et al.*, 2005; Xiao *et al.*, 2006; Braimoh and Onishi, 2007) and because of the limited physical resources available.

Recognizing the importance of land-use and land-cover studies in developing countries generally, and in arid and semi-arid areas of the Middle East in particular (see below), provides a key justification for this research. At the outset there is a need for detailed inventories of current and past land-use to set the context for the analysis of land-use change processes (e.g. Pax-Lenney *et al.,* 1996; Lambin and Ehrlich, 1997; Palmer and Van Rooyen, 1998; Rembold *et al.,* 2000; Ayad, 2005). Research is especially needed into the problems of urban expansion, because loss of productive land in the peri-urban fringe is currently being faced by many countries in the developing world. This means that results from specific case studies in the rural-urban fringe of arid and semi-arid areas will be of considerable relevance to the wider land-use change debates.

1.2 The DPSIR model as a conceptual framework for assessing land-use change

Researchers have adopted a variety of methods and models to investigate the causes of land-use and land cover changes at different temporal and spatial scales and in different disciplines (e.g. Lambin and Ehrlich, 1997; Irwin and Geoghegan, 2001; Rounsevell *et al.,* 2003; Verburg *et al.,* 2004a). One such approach is the DPSIR (driving forces, pressure, state, impact, and response) conceptual framework. This model will be used as the framework for analysing land-use change in this thesis. Indeed one aim of this thesis will be to apply and critique the DPSIR framework to understand the main drivers of land-use change in a more centralised, developing country (see below).

The DPSIR framework has been used to investigate a range of environmental problems. Many studies have focused on coastal, marine and water management (Elliott, 2002;

Walmsley, 2002; Bowen *et al.*, 2003; La Jeunesse *et al.*, 2003; Scheren *et al.*, 2004; Fassio *et al.*, 2005; Borja *et al.*, 2006; Lin *et al.*, 2007). In addition, a number of studies have addressed the problem of agricultural production and land-use change at a range of scales (e.g. Zalidis *et al.*, 2003; Holman *et al.*, 2005; Smaling and Dixon, 2006; Hasse *et al.*, 2007). There seems to be some consensus in the literature, therefore, that DPSIR is a suitable analytical framework to address land-use change issues in many different geographical contexts.

The idea of the DPSIR conceptual framework was originally derived from social studies and then generally applied in other disciplines, in particular for organising systems of indicators in the context of environmental and, later, sustainable development in an international context (e.g. UNEP/GRID-Arendal, 2002). The DPSIR framework can be interpreted as a more integrated version of the earlier PSR (pressure, state, and response) framework developed by the European Environment Agency (EEA) for organising information about the state of the European environment (OECD, 1993). It is based on the concept of causality chains for data synthesis, which links environmental information using indicators of different categories (driving forces, pressures, state, impacts and responses). The core sequence of the DPSIR framework as described by many studies (e.g. OECD, 1993; Costantino *et al.*, 2003) is shown in Figure 1.1 and is explained here briefly as a general overview (a thorough description of this framework will follow in Chapters 2, 3 and 5).

The DPSIR model has proven to be a useful framework for different types of analytical purposes and, in particular, to analyse relationships between human activities and the

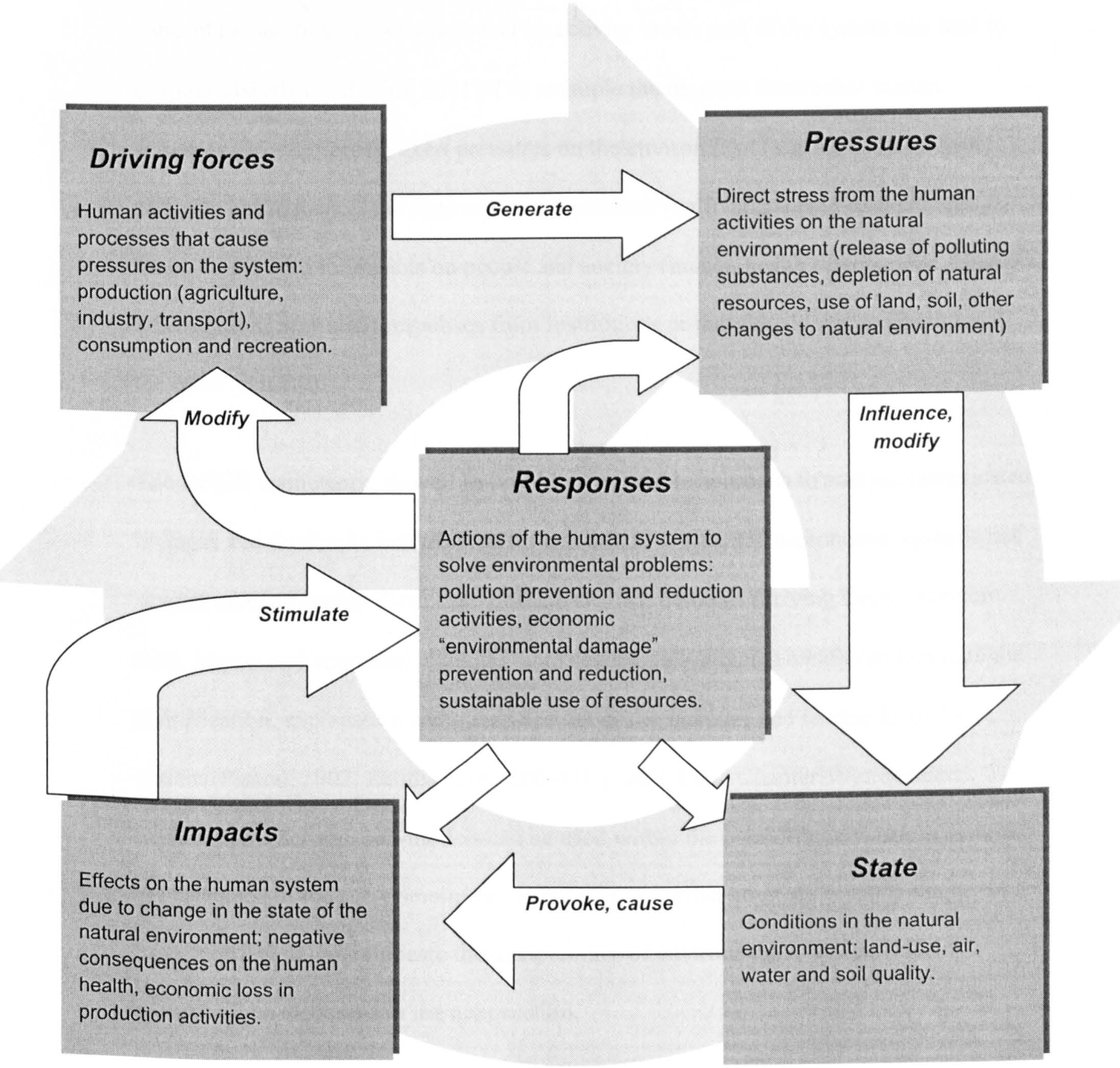


Figure 1.1: An overview of the DPSIR framework

(Source: Costantino *et al.*, 2003)

environment (Pisano, 2002; Kristensen, 2004). As Figure 1.1 highlights, the main concept behind this framework is that an activity in one part of the system can lead to changes elsewhere (Bellini, 2001). For example the diagram shows that human activities (driving forces) exert pressures on the environment (e.g. agricultural land) and, as a consequence, the state of the environment (agricultural land-use) changes. These forces lead to impacts on people and society (human health or economic damage) which in turn may elicit responses from institutions or individuals that feedback on all the other elements.

The DPSIR framework, as well as providing a flexible approach to analyse complicated linkages and feedbacks between causes and effects within socio-economic systems has several other strengths. First, each of the five main domains (driving forces, pressure, state, impact and response) is divided into several sub-domains which can facilitate the identification, explanation and quantification of the linkages and feedbacks in the system (Pisano, 2002; Zalidis *et al.*, 2004) (Figure 1.1 and Chapter 3 for detailed explanation). Second, sub-models can be used within the overall framework to explore the influence of the sub-domains in more detail. A further strength is that it can be used to good effect to communicate the complexities of environmental systems, and this aspect will be discussed in the next section.

1.3 The research gap: lack of critical applications of the DPSIR framework for the study of land-use change in arid regions of the developing world

The DPSIR model provides researchers and policy makers with a conceptual framework for both structuring and communicating policy-relevant research about the environment (Svarstad *et al.*, 2008). For example, Stocking (2002) asserted that "*the DPSIR model is useful to sort out cause and effect. The advantage is that it categorizes different aspects and allows us to focus on process links*" (Stocking, 2002 cited in FAO, 2002: 22). Furthermore, Svarstad *et al.*, (2008) argued that "*a presumed strength of the DPSIR framework is that it captures, in a simple manner, the key relationships between factors in society and the environment, and, therefore, can be used as a communication tool between researchers from different disciplines as well as between researchers, on the one hand, and policy makers and stakeholders on the other*" (Svarstad *et al.*, 2008: 116).

However, many researchers have argued that the DPSIR framework does not recognize complex interactions sufficiently. For instance, Sonneveld (2002) stated that "*the DPSIR framework represents...an often complicated, recursive dynamic processes. The big challenge, however, is to formalize these relationships in a quantitative manner that can be used for analytical purposes*" (Sonneveld, 2002 cited in FAO, 2002:22). Niemeijer (2002) also criticised the nature of the connections between the indicators in the DPSIR framework by suggesting that "*at present most indicator based studies present the selected indicators in the form of lists or tables that conveniently categorize the indicators as D, P, S, I, or R indicators. This hints at the causal position of each of* *the indicators in the causality chain, as it is often called, but fails to draw attention to the actual inter-linkages and causative patterns that relate one indicator to another"* (Niemeijer, 2002 cited in FAO, 2002:22). From the above arguments, it is clear that a better understanding of the DPSIR components and inter-linkages is needed before applying this framework in any given area, and that the case for applying the DPSIR model is not clear cut.

Originally a Western-based framework, DPSIR has mainly been applied in developed, democratic countries (e.g. OECD, 1993; EEA, 2001; Eurostat, 2001). Nonetheless, some researchers have used the DPSIR framework to compare developing and industrialised countries in terms of determining the most important components of the DPSIR framework for their case studies (e.g. Odermatt, 2004). However, overall there has been a lack of studies and investigations in developing countries using the DPSIR model as the main framework to address the interaction between the state of the environment and human activities (Bidone and Lacerda, 2004; Agyemang *et al.*, 2007).

This gap is particularly acute with regard to applications of the DPSIR model to understand land-use change in arid and semi-arid rural-urban areas of the developing world. This was recently reiterated by researchers from arid and semi-arid countries around the Mediterranean during a workshop held in Adana, Turkey in 2003, where commentators argued that DPSIR *could* form a useful framework for better understanding land-use changes in arid and semi-arid areas. For example, Zdruli *et al.* (2003: 7) argued that *"the general thinking is that the DPSIR framework could be a good tool to assess the impacts of human interventions on the status of the environment* *and the way the society reacts to such interventions*". At the same workshop, while one researcher proposed that *"each participating country could test the DPSIR framework"* (Steduto, 2003 cited in Zdruli *et al.*, 2003: 7), others proposed to test the impact of single crop or separate land degradation factors (*i.e.* erosion, salinity) using the DPSIR framework (e.g. Kapur, 2003 cited in Zdruli *et al.*, 2003: 7). Zdruli *et al.* (2003: 8), therefore, concluded that *"in the plenary session the bulk of the discussions was devoted to practical applications of the DPSIR framework and its endorsement as a tool for environmental impact assessments. Despite concerns that often such models are run by mathematicians (or informatics people) that are not so close to the real life and moreover the availability or lack of data brings to very discussable results, the overall agreement was that the DPSIR framework is accepted by the partners as a good tool and will be used extensively during the lifetime of the project, especially for developing policy guidelines for national and regional development"*.

These results from the Adana workshop highlight the need for further examination of the application of the DPSIR framework in arid and semi-arid areas of the developing world. This call for further analysis of how applicable the DPSIR framework is in analysing land-use change in vulnerable environments of the developing world forms the rationale for the focus of this thesis.

1.4 Aims and objectives

The above discussion has highlighted the relative scarcity of studies applying the DPSIR framework to understand land-use change in the rural-urban fringe of arid and semi-arid areas in the developing world. This study, therefore, aims to examine the application of the DPSIR framework for better understanding of agricultural land-use change in the rural-urban fringe in the eastern part of the Nile Delta of Egypt. The study will, first, provide a theoretical understanding of key factors that determine land-use change in the Nile River Delta of Egypt, and, second, investigate the relationships between these factors and land-use change. To address these aims the study has the following objectives:

1. To analyse patterns of land-use change in the eastern part of the Nile Delta over the past two decades using remote sensing information and other land-use data.
2. To investigate the importance of the different components of the DPSIR framework (driving forces, pressures, state, impacts and responses) for explaining land-use change in the eastern part of the Nile Delta.
3. To analyse the inter-relationships of components of the DPSIR framework for the eastern part of the Nile Delta
4. To evaluate and critique the application of DPSIR as a conceptual framework to assess land-use change in the rural-urban fringe of arid areas more generally.

1.5 Outline of the thesis

The thesis is structured following the main objectives. Chapter 2 provides a literature review as a context to this study, in which Figure 1.1 is used as a conceptual framework. The chapter defines and describes land-use, land-cover and intensification of land-use in general, and in developing countries and arid and semi-arid zones in particular. It discusses theories of land-use change and conceptualisations of land-use change and describes driving forces, pressures, state, impacts and responses as components of the DPSIR framework. In Chapter 3, the methodology and techniques used in the investigation will be outlined including justification for using the case study approach, remote sensing data, questionnaire data, participant observation, interviews with local people and experts in the study areas and census data. Chapter 4 describes land-use change in the two case study areas using data available from remote sensing over the period 1984-2003, the questionnaire, maps, and field photos (objective 1). The chapter will also discuss changes in agricultural policy as a response by decision-makers at the regional scale. Chapter 5 presents a description of applying the DPSIR framework to understand land-use change and the multi-causality of factors.

The remaining chapters follow objectives 2-4 as stated in Section 1.4. Chapter 6 investigates driving forces that affect land-use change in the two study areas and the relationships between driving forces and land-use change (objective 2). Chapter 7 examines pressures that affect land-use change in the two study areas. In Chapter 8, an investigation of the state of land-use and impact indicators that affect land-use change in the two study areas will be presented. Chapter 9 investigates response indicators by farmers that affect land-use change in the two study areas and the relationships between these responses and land-use change. Chapter 10 synthesises the most important indicators of driving forces and responses in the research region. The chapter also presents a ranking of driving force and response indicators for the eastern part of the Nile Delta (Probit model analysis) (objective 3). Chapter 11 evaluates the suitability of the DPSIR framework and data used in this study (objective 4). Chapter 12 provides conclusions to the study and discusses the need for future research.

Chapter 2: Theories of land-use and land-use/cover change models

2.1 Introduction

This chapter presents the key points in relation to theories of land-use/cover change models. It starts with definitions of land-use, land cover and land-use/cover change in general context and then presents a discussion and debates about different conceptual models that deal with land-use change in different spatial and geographical scales. It also underlines the importance of land-use change studies in arid and semi-arid areas in developing countries and the urgent need for such studies. The second half of the chapter discusses the most important driving forces affecting land-use change in different parts of the developing world. The last section of this chapter presents the DPSIR model as a conceptual framework for organising and categorising the driving forces, pressures, state, and responses indicators assumed to affect land-use change in the present study.

2.2 Land use, land cover, land-use/cover change and intensification of land-use

The aim of this section is to distinguish between the terms "*land-use*", "*land-cover*" and "*land-use/cover change*" in terms of the purpose of the application and the objectives of their use and to establish a better understanding of their meaning.

2.2.1 Definitions of land-use, land-cover and land-use/cover change

Definitions and descriptions of the terms "land-use" and "land-cover" vary with the purpose of the application and the objectives of their use. Investigations and studies of land-use change do not always employ similar definitions. It is, thus, important to look at different definitions and descriptions of these terms as they apply to the various geographical and temporal scales of interest. While the term "land-use" refers to the ways in which human beings employ the land and its resources (e.g. agriculture, urban development, mining), "land cover" describes the physical state of the land surface such as cropland, forests, wetlands, pasture, roads, and urban areas. At the global scale, land cover is a more meaningful term because it is based on ecological attributes. In contrast at the regional and local scales, land-use rather land cover is the focus for geographical and social enquiry because human activities influence the purpose for which the land is used. The Food and Agriculture Organization (1995) for example stressed the importance of human activities at the local scale: *"land-use concerns the function or purpose for which the land is used by the local human population and can be defined as the human activities which are directly related to land, making use of its resources or having an impact on them"* (FAO, 1995: 21). Similarly, Brown and Duh (2004) emphasised the key role played by individuals in terms of land-use, while decision-makers and institutions play a crucial role in terms of land cover.

Turner II *et al.* (1995: 20) defined "land-use" as involving *"both the manner in which the biophysical attributes of the land are manipulated and the intent underlying that manipulation – the purpose for which the land is used"*, and they described "land-cover" as *"the biophysical state of the earth's surface and immediate subsurface"*. In the same context, Skole (1994) argued that *"land-use itself is the human employment of a land-cover type, the means by which human activity appropriates the results of net primary production (NPP) as determined by a complex of socio-economic factors"* (Skole, 1994 cited in Briassoulis, 2000: 7).

It is evident, therefore, that definitions of land-use and land-cover are not identical especially when scale issues are taken into account. In other words, while some studies have paid attention to the meaning of land-use in a particular spatial scale (e.g. local scale in FAO's definition), others were interested in land-use investigation at the global scale (Graetz, 1994 cited in Briassoulis, 2000). There are two reasons behind such diversity in the meaning of land-use and land cover. The first reason is the differences between land-use/cover studies in terms of their objectives, and the second one is differences between these studies in terms of the scale of interest. It is, therefore, important to discuss the definition of land-use/cover change in connection with both the objectives of this study and in the context of the spatial scale of interest – an issue I will turn to next.

There are two broad categories of land-use and land-cover change: *conversion* and *modification*. *Conversion* refers to changes from one cover or use type to another, such as the conversion of forests to pasture. In contrast, *modification* involves maintenance of the broad cover or use type in the face of changes in its attributes and alterations of structure or function, without a comprehensive change from one type to another (Baulies and Szejwach, 1997). In this context, it is important to mention the term *agricultural intensification* especially in arid and semi-arid areas, where agricultural land intensification has been one of the most significant forms of land-cover modification, with dramatic increase in yields being the main feature of change during the last 30 years (Harris, 1996; Sutherland *et al.,* 1999; Hadasa *et al.,* 1999).

2.2.2 Land-use/cover change: issues and debates

There are huge variations in approach to land-use/cover change dependent on the study objectives, spatial scale of interest, and stakeholders addressed. Some land-use research has highlighted the importance of human-environmental interactions (Parker *et al.,* 2001; Veldkamp and Verburg, 2004) and in particular has emphasised the role of individuals. Other social scientists have been more concerned with investigating the role of society and its organisations. A number of researchers have tried to investigate the way in which entire social-ecological land cover systems interact (Verburg *et al.,* 2002; Soini, 2005; Verburg, 2006). Other researchers have focused on particular aspects of land-use and the influence of the social, economic or land-use planning aspect (Verburg *et al.,* 2001). The present research provides a comprehensive study of the land-use change by applying the DPSIR framework at the local *rural-urban fringe* scale and taking into account the main drivers with special emphasis on the role of individuals (farmers), their behaviour and decision-making, and other possible drivers that could affect land-use change at this level (exogenous drivers). Before analysing some of the major land-use change theories, it is necessary to highlight the various theories where land-use change is treated *explicitly* (as classified by Briassoulis, 2000). There are six interrelated sources of variation, in a decreasing order of importance (Table 2.1).

	Theories	*Approaches*
1	The purpose of the theoretical project	Descriptive, explanatory, and normative
2	The approach to theorisation	Individualist/ behaviourist theories and institutional/ structuralise theories
3	The spatial scale and level of spatial aggregation adopted	Theories of urban, regional and of global land-use change
4	The types of land-use considered as principal objects of analysis	Theories of particular types of land use – mainly residential, industrial, agricultural and forest land
5	The types of land-use change determinants taken into account	Theories prioritizing the economic or the social or the environmental determinants of land-use change or particular combinations of them
6	The treatment of the temporal dimension (which in the case of analysis of change, in general, is inherent in any project).	Static, quasi-static, and dynamic theories of land-use change

Table 2.1: Theories of land-use change (Source: Briassoulis, 2000)

Table 2.1 shows that theories and associated approaches of land-use change can be classified according to the purpose of the study, the approach used, the spatial scale level, types of land-use, causes of change and the temporal scale. It is, therefore, important to determine each category of the previous six components before conducting any land-use investigation.

The causes of land-use/cover change may be classified into three main categories; physical determinants, social drivers and economic drivers. The main physical factors affecting land-use/cover change are climate, water and soil. In particular the lack or abundance of water (Lorup *et al.*, 1998; Costa *et al.*, 2003), risk of soil erosion (Bakker *et al.*, 2005) and climate change (Al-Bakri *et al.*, 2001) have been highlighted as key factors. The key social drivers are agricultural policy, population growth, farmers' educational level, and gender role (Tanrivermis, 2003; Liu and Chen, 2006). The key economic drivers are globalisation and World Trade Organisation, subsidy availability, transportation cost and market prices (Bergeron and Pender, 1999; Srinivasan, 2005). While Mottet *et al.* (2006) have argued that physical drivers are the most important determinants of land-use change, other studies of land-use suggested that social and economic drivers are the most important determinants of land-use (Seto *et al.*, 2002; Long *et al.*, 2007b).

In the context of the present study, the DPSIR framework will be applied to achieve the main aims and objectives (Section 1.4), i.e. to contribute to an understanding of agricultural land-use change in the eastern part of the Nile Delta over the period 1984-2003.

The second component of land-use/cover change investigation (Table 2.1) is the approach to theorisation. In this context, it is important to stress that the meaning of "approach to theorization" (component 2) and the approach used for investigating land-use/cover change (component 6) are closely linked. While the first term refers to individualist, behaviourist, institutional or structuralist theories, the latter means the method used to analyse and explain land-use/cover change.

Land-use/cover change research has used different approaches to deal with the stakeholders (Kok *et al.*, 2007; Patel *et al.*, 2007). These include the community level factors such as public infrastructure, market structures, local organizations and technology, as well as individual farmers. In order to explain the community level factors further and discuss how they affect land-use/cover change, a closer examination of these factors is important.

Public infrastructure may have an important influence on land-use and viability of crop production. For example, new roads may reduce the transportation cost and supplying irrigation water may overcome the rainfall deficit. *Market structures*, including the presence of input suppliers, transport service and market channels, affect land-use by opening up the opportunities available to farmers. Local market deficiency, land or labour scarcities and lack of credit can all constrain adoption of new technologies and land-use change, particularly for crops whose resource requirements exceed the family's labour and capital availability. *Local organizations and institutions* may affect land-use choices by regulating usage at specific points (e.g. water sources) or by imposing restrictions on certain practices, such as use of chemical fertilizers or water. Producer associations or cooperatives may also reduce risk by importing external resources. Local institutional mechanisms that facilitate the exchange of labour may also enable farmers to allocate plans to higher intensity use. When *new technologies* are involved, farmers also critically rely on advice from outside sources, and the availability of extension services may be a critical factor to intensification.

The third component of land-use/cover change theories (Table 2.1) is the spatial scale issue. The purpose of the theoretical study of land-use change has been shown to dictate the scale of the investigation to some extent (see the discussion of component 1). Land-use/cover change can only be understood with reference to scales above and below those of interest (see chapter 3). For example, changes at a local level have the potential to influence changes at a regional level; rapid land-use change in one locality could lead to change in regional policy. It is, therefore, possible to recognise the influence of some factors which affect land-use/cover change operating at national or global level on land-use/cover change at local level (e.g. the role of globalisation and WTO). At the same time, some drivers which affect changes in land-use/cover at the local level can affect land-use/cover change at regional, national or global scales (e.g. policy, transportation). Conversely, incentives and regulations imposed at a higher level (national or global), such as policy changes, are translated and realized by human decision-making at the local level.

The fourth component of land-use/cover change theories (Table 2.1) is the types of land-use/cover which are considered as the principal objects of analysis. Studies of land-use/cover change have investigated changes in land-use and cover in rural, urban and rural-urban fringe areas in many parts of the developed and developing world. Three main types of land-use/cover have been the prime subject of such studies: agricultural land-use, forest and pasture and residential and industrial land-use. There is general agreement that agricultural land is declining in extent globally due to urban expansion (Robinson, 2004; Valeria and Tonts, 2005). Land-use competition in the rural-urban fringe, in particular, has been a major issue in the debate on land-use change

(Singh, 2003). The importance of investigating land-use in the rural-urban fringe, especially in arid and semi-arid areas, comes from considering the competition between agricultural and non-agricultural land-uses which is a key concern of the present study.

The fifth component of land-use/cover theories is the determinants (driving forces) of land-use/cover change (Table 2.1). A detailed discussion about driving forces affecting land-use/cover change will be presented in Section 2.4 in this chapter.

The final component of land-use/cover change theories as shown in Table 2.1 is the type of land-use/cover change analysis. Studies of land-use/cover change have followed a variety of methods and adopted various models and conceptual frameworks to investigate the causes of land-use and land cover changes at different temporal and spatial scales and in different disciplines (e.g. Lambin *et al.,* 1997; Irwin and Geoghegan, 2001; Rounsevell *et al.,* 2003; Verburg *et al.,* 2004a). Table 2.2 shows the

What is already known on land-use/cover change	*What one needs to Know on land-use/cover change*	*Model category*	*Modelling approach*
Where and when in the past	When in the future (short-term)	Stochastic	Transition probability models
	Why in the past (proximate causes) Where in the future (short-term)	Empirical, statistical	Multivariate statistical modelling Spatial statistical (GIS-based) models
Where, when and why in the past	When in the future (long-term)	Process-based, mechanistic	Behavioural models and dynamic simulation models Dynamic spatial simulation models
	When and where in the future (long-term) Why in the future (underlying causes)	Analytical, agent-based, economic	Generalised Von Thunen models
	Why in the future (underlying causes; scenarios)		Deterministic and stochastic optimisation models

Table 2.2: Land-use/cover change models (source: Lambin *et al.,* 2000)

four broad categories of land-use change models (as classified by Lambin *et al.*, 2000).

The previous argument has focused on the conceptualisation land-use/cover change in a general context with special emphasis on the five components that should be included in any analysis of land-use change study. In the next section, an explanation will be given of the urgent need for more studies on land-use change in developing countries particularly in arid and semi-areas.

2.2.3 Land-use change in developing countries, arid and semi-arid areas

In an assessment of population levels in the world's dry lands, the Office to Combat Desertification and Drought (UNSO) of the United Nations Development Programme (UNDP) showed that 54 million km^2 or 40% of the global land area are drylands. About 30% of this area falls in the arid region, 44% in the semi-arid region and 26% in the dry sub-humid region. A large majority of drylands are in Asia (34%) and Africa (24%), followed by the Americas (24%), Australia (15%) and Europe (3%) (UNSO, 1997). Developing countries are facing increasing pressure on agricultural land. This comes from rapid population growth, unplanned and random urban encroachment and the lack of effectual policies to tackle desertification, soil salinisation and land degradation. There is, therefore, an urgent need for more studies to resolve these problems (Hitzhusen, 1993; Jolly and Torrey, 1993; Tinker *et al.*, 1997; Pretty *et al.*, 2003; Ayad, 2005). The severity of such problems is more serious in arid and semi-arid areas where the restricted availability of irrigated water and inadequate arable land are limiting factors in agricultural production and food security (Viglizzo *et al.*, 1997; Wallace, 2000; Robinson, 2004; Kamusoko and Aniya, 2007).

To address the importance of investigating land-use/cover change in developing countries generally, and arid and semi-arid areas in particular, it is, thus, of crucial importance to discuss the most important physical (external) and socioeconomic (internal) characteristics that affect land-use/cover change in these areas (see Section 2.4). First, however, a discussion and explanation of different theories and application of land-use change and methods followed to address these issues are presented next.

2.3 Theories of land-use change (physical, socio-economic, and policy related driving forces)

The ability to estimate land-use and land-cover change and, eventually, to predict the consequences of change, will depend on the capability to understand the past, present, and possible future drivers of land use/cover change (Loveland *et al.*, 2003). There are two main interrelated questions which are key for analysis of land-use change: what drives or cause land-use change and what are the environmental and socio-economic impacts of land-use change (Briassoulis, 2000)?

Understanding trends and developments in land-use change in relation to the driving factors that control it provides essential information for land-use planning and sustainable management of resources (Verburg *et al.*, 2004c). However, since the accurate meaning of "drivers" or "determinants" or "driving forces" of land-use change is not always clear in land-use change studies (Briassoulis, 2000), a conceptualisation of land-use change as well as clarification and explanation of debates of driving forces that cause land-use/cover changes will be presented in the following paragraphs.

The purpose of this section is to discuss land-use change in a conceptual sense in order to clarify the term and to address land-use change ideas, in addition to presenting a representative collection of theories of land-use change. Golley (2000) defines change as *"the opposite of stability or fixity"* (Golley, 2000 cited in Mander and Jongman, 2000:3). Other definitions suggest that change means *"alteration, modification, an event that occurs when something passes from one state or phase to another"* or *"a relational difference between states; especially between states before and after some event"* (WordNet 2.0 website, 2004). In the context of land-use/cover change, *conversion* and *modification* are the main types of change, as mentioned in the previous section.

In a land-use and land-cover change study, Turner II *et al.* (1995) reviewed a framework for understanding land-use and cover situations. They argued that the use of direct observation from a variety of empirical sources of land-cover change, including satellite remote sensing, national census and land-cover inventories, and field based measurements can be used to calibrate directly empirical, spatially detailed models of land-cover change. Their approach emphasised the need to make observations with the appropriate frequency and spatial scale to quantify land-cover change and land-use distributions explicitly. Land-cover, according to this approach, changes in multiple ways. It can change as a result of independent changes in biophysical drivers (climate and atmospheric change, natural erosion and deposition) (Viglizzo *et al.,* 1997; Huang and Cai, 2007) , human activity (Krausmann *et al.,* 2003; Long *et al.,* 2007a) either through direct alteration such as deforestation (Nelson and Geoghegan, 2002; Mertz *et al.,* 2005) or mediated through the biophysical realm (e.g. groundwater withdrawal leading to a lowered water table, reduced stream flow and altered vegetation) or through a more complex chain of human activity in the biophysical world (Lambin *et al.,* 2001; Aspinall, 2004; Veldkamp and Verburg, 2004; Mottet *et al.,* 2006) which feeds back to human activity, which then directly alters land-cover. Figure 2.1 shows the conceptual framework used in this approach. This diagram is clearly theoretical and capable of providing guidance to empirical researchers. It makes clear that studies of land-use/cover change need to consider both social and biophysical drivers. It shows the central role of land managers and highlights the importance of feedbacks. The figure also indicates that the interaction between natural causes, social and economic drivers influence individuals' (farmers) behaviour and affect their decision-making in terms of land-use at the local level which, in turn, determines land-cover at a higher scale (regional, national). At the same time, land cover could be directly affected by regional and global change (climate change, soil condition, water availability) or by socio-economic (globalisation, WTO) and technological (transportation) drivers at higher scales (national, global) or by the interaction of both. However from a theoretical and empirical perspective, Figure 2.1 is also problematic. This is because, while the boxes themselves are sufficiently broad (social systems, ecological systems and land-use system), the terms are very vague. In Figure 2.1, almost all the links involve feedbacks. There is a tendency in this diagram to show that everything is connected to, influenced, and is influenced by everything else. In the context of the present study, the key point is to stress that land-use is a function of the interrelationship between 'man, mind and land' (Firey, 1960). In other words, the term land-use embraces the endeavour; aspirations, education and cultural identity of individuals who are part of a larger social, political and economic system, all working within the constraints of particular physical resources such as climate, soil type and geomorphology.

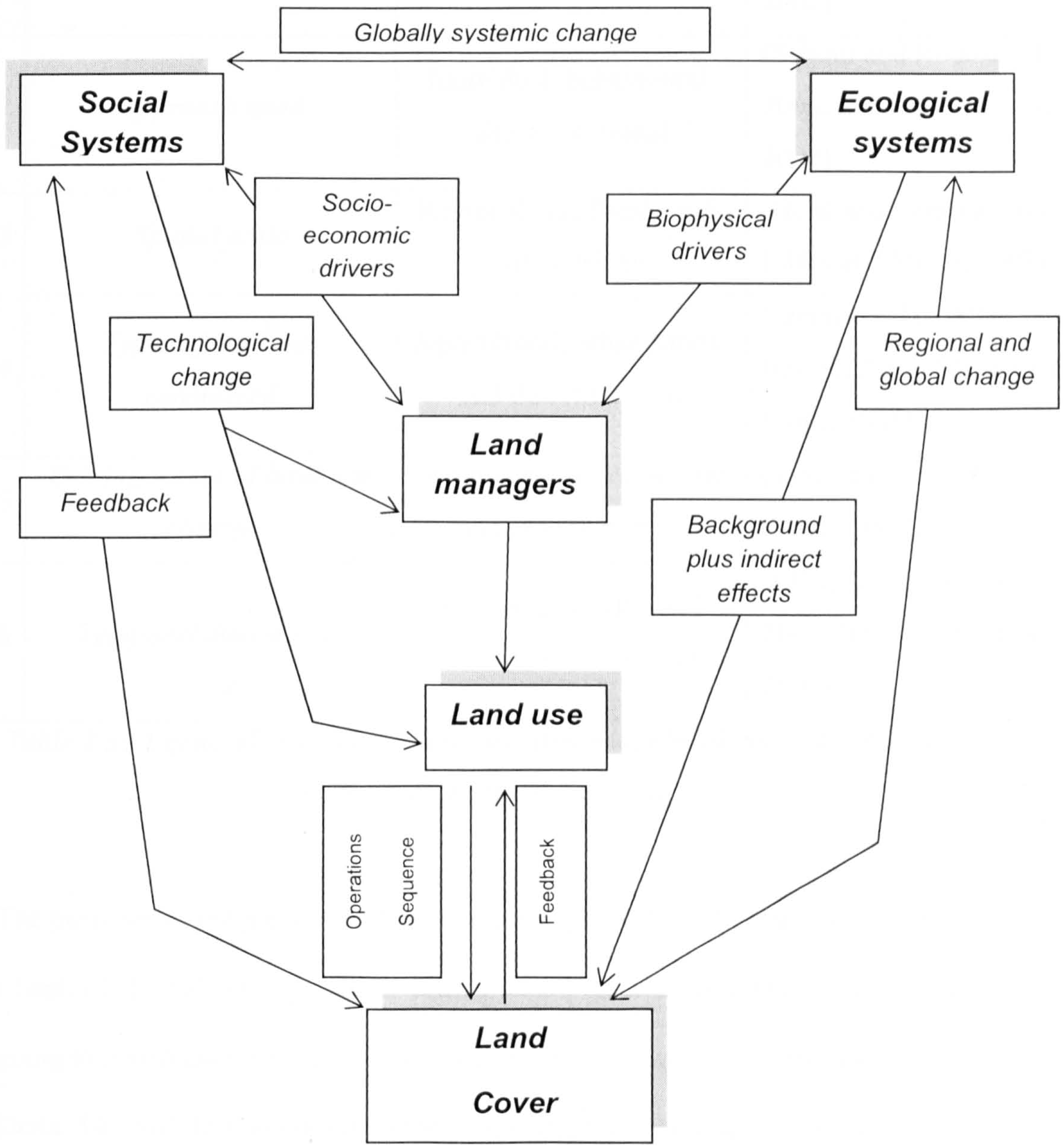


Figure 2.1: A framework for Understanding Land-Use/cover Change

(Source: Turner II *et al.*, 1995: 35)

Table 2.3 provides a summary of the application of theories of land-use change used in this study.

	Theoretical structure	*This study application*	*Relevant references*
1	***Purpose of study***	Descriptive, and explanatory	(Serneels and Lambin, 2001; Geist and Lambin, 2002)
2	***Approach used***	Individual, behavioural, and institutional	(Schmit and Rounsevell, 2006; Schneeberger *et al.*, 2007)
3	***Spatial scale***	Regional, and local rural-urban fringe	(Geist and Lambin, 2002; Libby and Sharp, 2003)
4	***Types of land-use considered***	Agricultural, urbanisation, and desertification	(Zhang *et al.*, 2000; Bellini, 2001; Wilson and Juntti, 2005)
5	***Driving forces of land-use change***	Cultural, social, economic, and environmental	(Verbist *et al.*, 2005; Quan *et al.*, 2006)
6	***Temporal dimensions***	Dynamic DPSIR, and 1984, 1992 and 2003	(EEA, 2001; OECD, 2003; Haase and Nuissl, 2007)

Table 2.3: A general structure of land-use theory applications in this thesis

(Source: Author after Briassoulis, 2000)

The purposes of the present study have been explained in Chapter 1. As mentioned in Chapter 1, (see also Chapter 3 for further detail) the scale of interest that this study is going to investigate is the local *rural urban fringe* in two contrasting areas of the Nile Delta. This will lead to consideration of specific types of land-use in the two areas (e.g. agricultural land, urbanisation and desertification). Causes of land-use change in these areas are linked, from cultural, social and economic characteristics of people who engage in agricultural production (farmers) to environmental changes (climate change, soil conditions). The discussion of these drivers is presented in the next section.

2.4 Driving forces, pressures, state, impacts, and responses of land-use change

Land-use and land-cover change is driven by the interaction in space and time between the biophysical context and human dimensions, including local culture and socioeconomic characteristics (Zhai and Ikeda, 2000; Bicik *et al.,* 2001; Lambin *et al.,* 2001; Veen and Otter, 2001; Muller and Zeller, 2002; Pijanowski *et al.,* 2002; Parker *et al.,* 2003; Veldkamp *et al.,* 2004). Involvement in the dynamics of land-use systems is not possible without an appropriate understanding of the driving forces in these systems and their performance (Verburg *et al.,* 2001). It is, therefore, essential to discuss the possible driving forces that cause land-use/cover change. The majority of land-use and land-cover change studies have paid attention to the driving forces that influence these changes in order to obtain better understanding of the current state of land-use and land-cover conditions and forecast possible future trends.

2.4.1 Driving forces of land-use/cover change

There has been a broad debate amongst those who engage in land-use/cover change studies about the exact meaning of driving forces or drivers or determinants of land-use/cover change. While Richards (1990) in his book "Land Transformation" argued that world markets, population growth and the interaction between the technological factors and natural resources are the most important driving forces of land-use change, Meyer and Turner II (1994) and Rubiano (2000) suggested that human actions rather than natural forces are the most important causes of land-use/cover change.

Research on land-use/cover change has distinguished between two types of driving forces that cause changes in land-use; *proximate causes* and *indirect drivers* or *underlying driving forces* of land-use change. Geist and Lambin (2002) working in the tropics for example, tried to generate from local scale case studies a general understanding of the *proximate causes* and *underlying driving forces*. They identified three broad clusters of *proximate causes*: agricultural expansion, infrastructure extension, and other factors. Each land-use category was additional subdivided. For example, agricultural expansion was divided into permanent cultivation, shifting cultivation, cattle ranching, and colonization. *Underlying driving forces* were categorized into five broad groups; demographic, economic, technological, policy and institutional and cultural factors. Each one of these clusters was further subdivided into specific factors. For example, cultural or socio-political factors were divided into public attitudes, values and beliefs, and individual or household behaviour.

Sherbini (2002), meanwhile, argued in his review of 152 case studies (78 from Latin America, 55 from Asia and 19 from Africa) that the *proximate causes* are one of the most important type of land-use change including factors such as cropland extension, intensification of agriculture and livestock expansion, especially where environmental fragility is linked to periodic drought, poor soils, or steep slopes. The indirect drivers or *underlying forces* of land-use change include population density and growth, migration, and policies that encourage or subsidize unsustainable practices.

Many researchers have attempted to group together land-use and land-cover change driving forces (Table 2.4). While some authors who have grouped driving forces that affect land-use/cover change have paid considerable attention to social, economic, cultural, political and technological drivers thereby neglecting of physical drivers (Turner II *et al.*, 1993; Panayotou and Sungsuwan, 1994; Lambin, 2004; Quan *et al.*, 2006; Long *et al.*, 2007b), others have also taken into account environmental factors such as climate change and soil conditions (Prieler *et al.*, 1998; Pfaff, 1999; Briassoulis, 2000; Bato, 2000;Wood *et al.*, 2004).

Author, date	***Driving forces affecting Land-use/cover change***
(Turner II *et al.*, 1993)	**(1)** Population. **(2)** Level of affluence. **(3)** Technology. **(4)** Political economy. **(5)** Political structure. **(6)** Attitudes and values of individuals and groups.
(Panayotou and Sungsuwan, 1994)	**(1)** Population density. **(2)** Wood prices. **(3)** Income and distance to city (remoteness).
(Lambin and Ehrlich, 1997)	**(1)** Long-term natural changes in climatic conditions. **(2)** Geomorphologic and ecological processes such as soil erosion and natural vegetation dynamics. **(3)** Human induced alterations of vegetation cover and landscape (deforestation and land degradation). **(4)** Inter annual climatic variability (recurrent droughts and floods). **(5)** Human induced climatic changes.
(Poudevigne *et al.*, 1997)	**(1)** ***Agricultural practices***: lead in turn to intensification of some areas and abandonment of others. **(2)** ***Urbanization***: modifies the structure and organization of the landscape. **(3)** ***Conservation policies***: check theses changes in certain zones.

Table 2.4: A summary of previous studies discussed driving forces affecting land-use/cover change *"continued"*

(Prieler *et al.*, 1998)	(1) ***Environmental conditions***: climate, soil characteristics, water availability, and environmental pollution. (2) ***Social context***: demographic factors (population density, migration), markets for agricultural and forestry products, attitudes and values (toward the landscape, cultural heritage and natural conservation), and traditional land use. (3) ***Policies related to land-use planning***: development plans, and legal frameworks (land use policy, land-use planning). (4) ***Agriculture and forestry***: size of farms/forest, production structure, ownership structure, policies (subsidies, taxes, agricultural pricing policies), and forestry/farmland use (commodity production, recreation, protected areas). (5) ***Former land-use structure and change.***
(Pfaff, 1999)	(1) ***Land characteristics***: such as soil quality and vegetation density. (2) ***Transportation costs***: such as distance to major markets and both own and neighbouring county roads. (3) ***Government development projects***: that appeared to affect clearing.
(Briassoulis, 2000)	(1) ***The biophysical drivers:*** weather and climate variations, landform, topography, volcanic eruptions, plant succession, soil types and processes, drainage patterns, availability of natural resources. (2) ***The socioeconomic drivers:*** demographic, social, economic, political and institutional factors and processes such as population and population change, industrial structure and change, technology and technological change, the family, the market, various public sector bodies and the related policies and rules, values, community organization and norms, property regime.

Table 2.4: A summary of previous studies discussed driving forces affecting land-use/cover change "continued"

(Bato, 2000)	(1) *Climatic conditions.* (2) *Natural disasters:* like landslides from earthquakes and soil erosion. (3) *Human activities:* through agriculture, deforestation and reforestation.
(Tanrivermis, 2003)	(1) Agricultural productivity and intensification. (2) Changes in population density. (3) Industrialization, urbanization and tourism. (4) Agricultural mechanization and use of agri-chemicals.
(Lambin, 2004)	(1) Drivers that the demand that will be placed on the land such as population and affluence. (2) Drivers that control the intensity of exploitation of the land (e.g. Technology). (3) Drivers that are related to access to or control over land resources (political economy). (4) Drivers that create the inducements that motivate people who make decisions such as political structure, attitudes and values.
(Wood *et al.*, 2004)	(1) Sustainable intensification of agriculture (2) Climate (3) Population pressure (4) Development projects (5) Commodity production (6) Forestry practices (7) Fallow cycles (8) Land tenure
(Quan *et al.*, 2006)	(1) Urbanization and industrialization. (2) Infrastructure and agricultural intensification. (3) Increased affluence of the farming community. (4) Policy factors.
(Long *et al.*, 2007b)	(1) Rapid industrialization. (2) Urbanisation. (3) Population growth. (4) Economic reforms.

Table 2.4: A summary of previous studies discussed driving forces affecting land-use/cover change (Source: Author)

In order to elaborate the debate of driving forces affecting land-use change further, an analysis of different contributions of studies investigated causes of land-use change is of crucial importance.

In a study aimed at discovering driving forces affecting land-use change at a regional scale in a developing country (Kajiado District, Kenya), Campbell *et al.* (2003) adopted a political ecology model as a conceptual framework for the investigation (Figure 2.2). They suggested that land-use change results from the interaction between society, reflecting economic, social and political processes, and the physical environment. Further, these interactions occur between different scales (global, national, local) over time and space. In this conceptualisation, while the implications of environmental changes are often discussed in terms of global consequences, there is growing recognition that many of the critical causes arise from interactions between societal and biophysical processes at the local level. The decisions that lie behind these actions which create environmental problems are influences by a wide variety of interrelated factors (driving forces) that emanate from both local and external circumstances and that cross boundaries between societal and environmental systems.

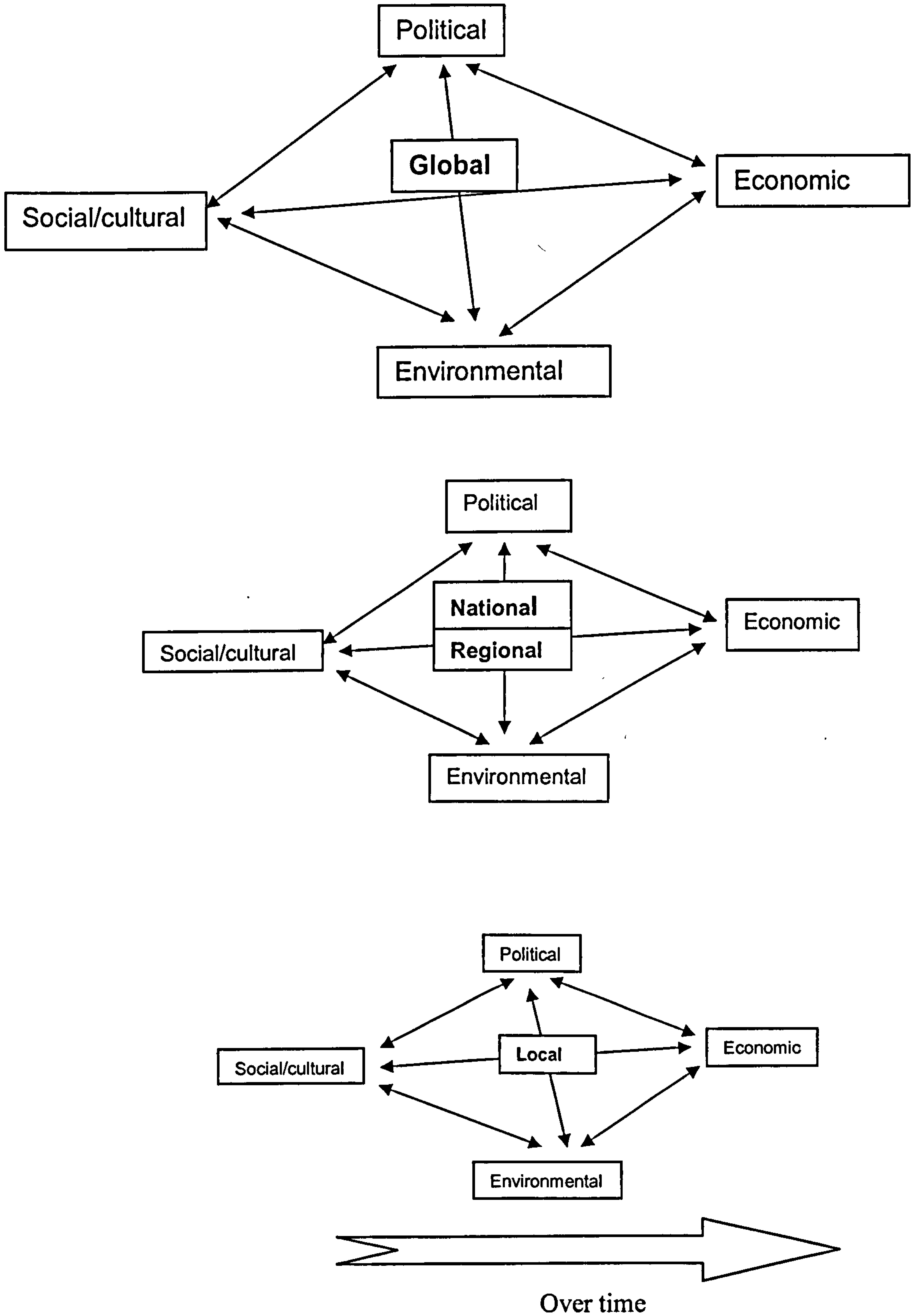


Figure 2.2: "The Kite"; a political ecology framework

(Source: Campbell *et al.*, 2003)

Their study concluded that driving forces affecting land-use change in their study area (local scale) are divided into four main categories; economic driving forces, institutional/policy driving forces, social/cultural driving forces and environmental factors. Economic and institutional/policy driving forces are subdivided into international, national and local. Social/cultural driving forces are subdivided into national and local. Environmental factors include rainfall, surface water, land cover and soils. At the international level, the main economic driving forces are market forces, trade policy and agreements and structural adjustment/ resumption and suspension of aid. At the national level the main economic driving forces are the national economic policy, agricultural pricing, transport and exchange rates. The main social/cultural driving forces at the national level are urbanisation, immigration and leadership while at the local level population dynamics (growth, migration), cultural change (leadership issues debate), gender role and ethnic heterogeneity are key.

Veldkamp and Fresco (1996b) and Verburg *et al.* (1999) attempted to develop a spatially explicit, multi-scale, quantitative description of land-use changes through the determination and quantification of the most important (assumed) bio-geophysical and human driving forces of agricultural land-use on the basis of the actual land-use structure. They designed a Conversion of Land Use and its Effects (CLUE) framework (Figure 2.3). The CLUE methodology is based on the analysis of land-use change as a complex multi-level system. Authors of the CLUE model suggested that land-use changes operate at the interface of multiple social and ecological systems. The concepts involved in the CLUE methodology are:

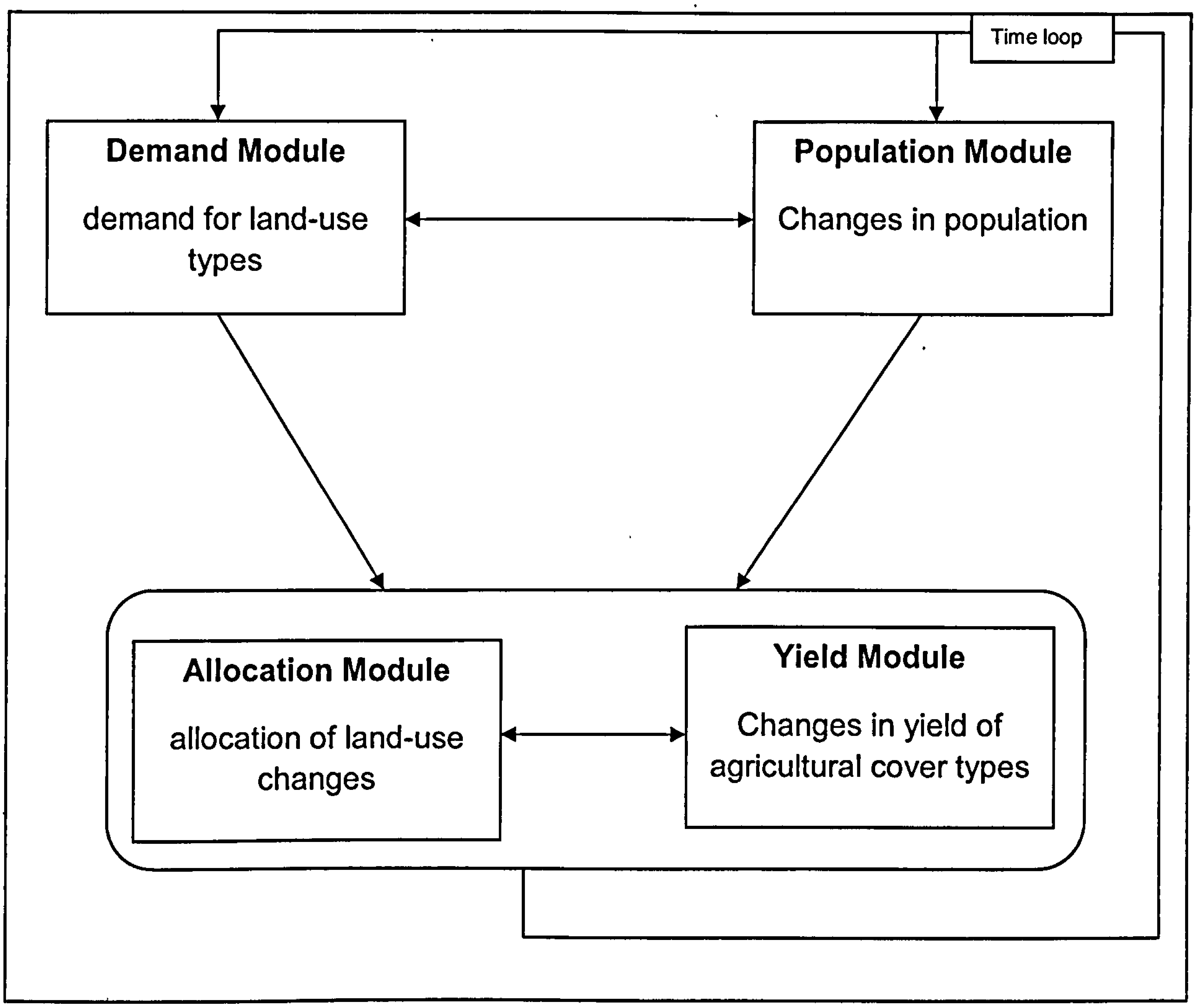


Figure 2.3: General structure of the CLUE modelling framework.
(Source: Verburg *et al.*, 1999)

- Connectivity: locations that are spatially distant can influence each other as a consequence of direct processes (e.g. sedimentation in the lowlands is a direct result of erosion in the uplands), neighbourhood effects or feedback over higher scale levels.
- Hierarchical organization: higher level processes can steer and constrain lower level processes while, at the same time, higher level features might emerge from lower level dynamics (e.g. the establishments of a new fruit-tree plantation in an

area near to the market might influence prices in such a way that it is no longer profitable for farmers to produce fruits in more distant areas).

- Stability and flexibility: land-use systems are able to absorb disturbances before the structure of the system is changed (e.g. farmers will not change land-use directly upon fluctuations in market prices of agricultural products).
- Driving forces: a large set of socio-economic and biophysical factors can be seen as the "drivers" of land-use change, steering the rate and/or location of change.

In this framework, the authors suggested that land-use changes are the result of many interacting processes. Each of these processes operates over a range of scales in space and time. These processes are driven by one or more of these variables that influence the actions of the agents of land-use and cover change involved. These variables are often referred to as underlying driving forces which support the proximate causes of land-use change, such as agricultural expansion. The authors also highlighted that these driving forces include demographic factors (e.g. population pressure), economic factors (e.g. access to credit), technological factors (irrigation system), policy (agricultural policy changes) and institutional factors, cultural factors and biophysical factors. These factors influence land-use change in different ways. Some of these factors directly influence the rate and quantity of land-use change (e.g. the amount of agricultural land converted to settlement area due to population growth). Other factors determine the location of land-use change (e.g. the suitability of the soils for agricultural land-use), especially the biophysical factors which cause constraints to land-use change at certain locations leading to spatially differentiated pathways of change.

The CLUE model is different from models solely based on an empirical analysis of land-use change (e.g. Mertens and Lambin, 1997; Pijanowski *et al.,* 1997). The advantage of this model is the explicit attention for the functioning of the land-use system as a whole, the capability to simulate different land-use types at the same time and the possibility to simulate different scenarios. The selection of driving forces for the CLUE model is based on the theoretical relationships between driving forces and land-use change. In order to avoid erroneous correlations, only those driving forces are taken into account for which a theoretical relationship with land- use is known.

The determination of the driving forces of land-use changes is, therefore, a challenging issue of discussion. There is no unifying theory that includes all driving forces relevant to land-use change. Therefore, the present study will investigate driving forces of land-use change which have theoretical relationships with land-use change. A review of the possible driving forces that influence land-use change with explanation of each one is presented next.

2.4.2 Climate change

Climate change is one of the key physical drivers that influence agricultural production and land-use/cover change (Loveland *et al.,* 2003; Robinson, 2004). There is a growing probability that global climate change will soon start to have a noticeable and increasingly severe environmental and socio-economic impacts across many parts of the world (Xi-Ping *et al.,* 2003; UNFCCC, 2004). However, many of the developing countries which have extensive arid and semi-arid areas are already suffering from environmental degradation. Climate change will exacerbate environmental problems with serious implications for agriculture production, food security and water resources (Sivakumar, 2007). Moreover, being geographically more exposed to the impacts of climate change, many developing countries are vulnerable because they lack the required technologies, financial resources, and institutions or trained people to deal with the consequences. Variability in climate in arid and semi-arid areas will affect agricultural land-use and land cover patterns in two main ways: temperature and water availability. Higher temperatures may reduce crop yield and the crops may also require more irrigation water. However, there have been some negative impacts associated with irrigation processes when the natural drainage system is unable to cope with the additional water input. This excess water causes a rise in groundwater levels, and transports dissolved salts to the active root-zone and surface areas and eventually damages crops (Robinson, 2004).

2.4.3 Globalisation and World Trade Organisation (WTO)

The concept of globalisation reflects a key principle that "*developments in one part of the world have important consequences for the life chances of individuals and areas in other parts of the globe*" (Gibbs, 2000:1). During the last decade, many developing countries which experienced both rapid economic growth and even more rapid economic decline have become involved in the wider processes of globalisation (Mertz *et al.*, 2005). Globalisation can include a variety of events and processes, but those that appear to mainly affect agricultural production and land-use change have been summarised by Olson *et al.* (2004) to include firstly, rapidly changing international and national markets for a variety of agricultural and industrial commodities, and changing national access to international markets; secondly, increased competition between and within countries among those producing globally marketed commodities, resulting in variable and often declining producer prices; thirdly, economic diversification as farmers respond to new opportunities; and lastly, international influence on national policies and regulations (e.g. type and quality of products exported and sources of inputs). Robinson (2004) argued that there are differing views about the effects of globalisation and global capitalism on developing countries. On the one hand, developing countries will increasingly be brought within the "global orbit" and in addition to being a large market for food and commodities produced in developed countries, farmers and food processors in developing countries will play a significant role in this process. Also, many developing countries will be able to take advantages of the market of developed countries for both primary produce and processed food. On the other hand, anti-globalisation groups suggest that freer trade simply plays into the hands of the rich developed countries, allowing existing Western transnational corporations (TNCs) to further dominate the markets of the developing countries (Robinson, 2004). The influence of the WTO on land-use change at the regional and local level can be highly variable, and can include both the reduction of former markets and export opportunities (e.g. coffee in East Africa), and the development of entirely new opportunities (e.g. flower trade).

There are different ways in which globalisation and the WTO can affect land-use change at national, regional and local levels in a developing country. For example, global businesses such as TNCs operate semi-independently of international trade agreements. For many of these businesses, geographic location may be less important than the cost of labour in their commodity chain. Therefore, the geographic location of global businesses often changes to reduce production and distribution costs (e.g. labour costs or inputs costs), which in turn may have impacts on the local socio-economic structure that influences land-use options and decision-making. Another way in which globalisation and the WTO affect land-use change is through technology transfer. Technology transfer (e.g. new types of irrigation systems, genetically modified seeds) is a way in which innovations diffuse from one region to another. Innovations spread when they prove successful in one region and other regions wish to adopt them. The introduction of such innovations, therefore, may lead to different land-use practices. For example, genetically modified seeds may increase agricultural output, and at the same time require different inputs and investments, such as irrigation and fertiliser and pesticide use. A third way in which globalisation could affect land-use change is market integration. Market integration may have a range of land-use consequences, especially on agricultural production systems, including expansion of cultivated areas, changes from subsistence to cash crops, intensification of production (including increased use of inputs) (Global Land Project Team (GLP), 2005).

2.4.4 Population growth

Table 2.4 above shows that a large number of land-use change studies have considered population growth as one of the driving forces affecting land-use change in different parts of the world (Turner II *et al.,* 1993; Panayotou and Sungsuwan, 1994; Prieler *et al.,* 1998; Briassoulis, 2000; Tanrivermis, 2003; Wood *et al.,* 2004; Long *et al.,* 2007b).

Population growth in land-use change studies is associated with the expansion of urban settlements and industrial areas towards agricultural land especially in developing countries (Verburg *et al.,* 1999a; Pauchard *et al.,* 2006; Braimoh and Onishi, 2007). There have been two main assumptions with which research on land-use change have approached the relationship between population growth and land-use change. On the one hand, some researchers (Malthusian) have argued that population growth will translate into an agricultural crisis, evidenced by land fragmentation, environmental deterioration, food shortage and general poverty (Bilsborrow and Pan, 2001; Hunter *et al.,* 2001) However, an alternative school of thought (Boserupian) has suggested that population increase will stimulate agricultural growth through the intensification of agriculture, leading to improvements in food availability and general economic development (Omosa, 1998; Bergeron and Pender, 1999). Sage (1994) elaborated this argument further and suggested in addition to the two previous scenarios (Malthusian and Boserupian) two additional options resulting from population growth impacts on agriculture and land use change. The first option is that population growth can be scale neutral in terms of the local resource base, either through the importation of food from elsewhere or as excess population out-migrants, resulting in no demographic pressure for agricultural change. The second option is that there may be reverse effects on population or feedback loops when changes in the productive potential of the local environment influence the determinants of population: fertility, mortality, and migration.

Robinson (2004) argued that in the rural-urban fringe in particular, where competition between agricultural and non-agricultural land uses is at its most intense, the processes of urbanisation influence agricultural production and land-use change in four ways: "*loss of farmland for urban development; reduction in the amount of farmland produces smaller farming units and the fragmentation of holdings; speculation in anticipation of development can lead to a deterioration in farming standards. Similar deterioration may be associated with increased trespass and vandalism; and spread of rural retreaters or hobby farmers who farm on a part-time basis*" (Robinson, 2004: 210). Although urbanisation has a significant influence upon agriculture and land-use change at the interface between the urban and the rural, it is not the only possible driving force in explaining this change. While Herington (1984) emphasised that driving forces contributing to the urbanisation of the rural-urban fringe include for example economic factors (cost of transportation), individual desires, environmental values, housing availability, employment opportunities, and public policy, Sage (1994) suggested that although population growth is indeed one factor that acts to influence land-use changes, it does so in association with two other variables: technological capacity and levels of consumption.

Based on the discussion provided, the present study will examine the role of population growth as one of the possible driving forces affecting land-use change in the rural-urban fringe of the two study areas, taking into account other drivers associated with population growth such as transportation availability and cost which will be discussed next.

2.4.5 Transportation availability and cost

There has been a considerable interest in the role that transportation plays in the agricultural and economic development of both developed and developing countries (Kilkenny, 1998; Venables and Limao, 2002; Mijinyawa and Adetunji, 2005; Lambin and Geist, 2006). In many developing countries, rural transport infrastructure (e.g. local roads, tracks, footpaths, and bridges) used to access farms, markets, water supplies, schools, and clinics is often in poor condition for some or all of the year. Transport services- both large scale motorized means such as trucks, buses, pickups, and cars, and intermediate means such as handcarts, bicycles, motorcycles, and animal drawn carts- are often inadequate and too expensive for rural residents. While cost constrains the use of transport services, a lack of focussed demand restricts the development of cheaper, more efficient services (Starkey *et al.*, 2002).

Nowadays, farm transportation plays a key role in the agricultural and economic development of developing countries. It delivers all required inputs to the farm and transfers of harvests to the urban areas where they are mostly sold. These contributions assure the improvements in agricultural production, food availability in urban areas and improvement in the economy of rural communities (Klatzel, 2000). In a report presented to the World Bank which discussed transport as a factor and constraint in agricultural production and marketing in Africa, one of the key findings emphasised the need to travel and transport goods to and from the field as an essential task associated with agricultural activities of all income groups. For the majority of farmers, travel is associated with household subsistence in which the need to transport farm products is greatest during the harvest period (Airey, 1992).

Several studies have attempted to determine the relationship between transportation cost and land-use change. One of the most commonly utilised models used in the 1960s for agricultural land-use spatial patterns explanation was that of Johann Heinrich Von Thunen (1783-1850) (Clark, 1967; Robinson, 2004). His model, developed in 1826 was based on three limiting assumptions (Sinclair, 1967):

- Isolation. There is one isolated market in an isolated state having no interactions (trade) with the outside.
- Land characteristics. The land surrounding the market in entirely flat and its fertility is identical.
- Transportation. It is assumed there are no transport infrastructures such as roads or rivers and that farmers are transporting their production to the market using horses and carts. Transportation costs are dependent of the type of commodity being transported to the market as well as the distance involved.

Von Thunen argued that the cost of transportation of produce from the farm to the market is the most important force that determines land-use patterns distribution around the market centre. He suggested that land-use patterns are dependent on production cost, the market price and the transportation cost of the agricultural produce and expressed as follows (Figure 2.4):

$$\mathbf{R = Y\ (p\text{-}c) - Y\ f\ m}$$

Where:

- R = Rent per unit of land.
- Y = Yield per unit of land.
- p = market price per unit of yield.
- c = Average production costs per unit of yield.
- m = Distance from market (in kilometres or miles).
- f = Freight rate per unit of yield and unit of distance.

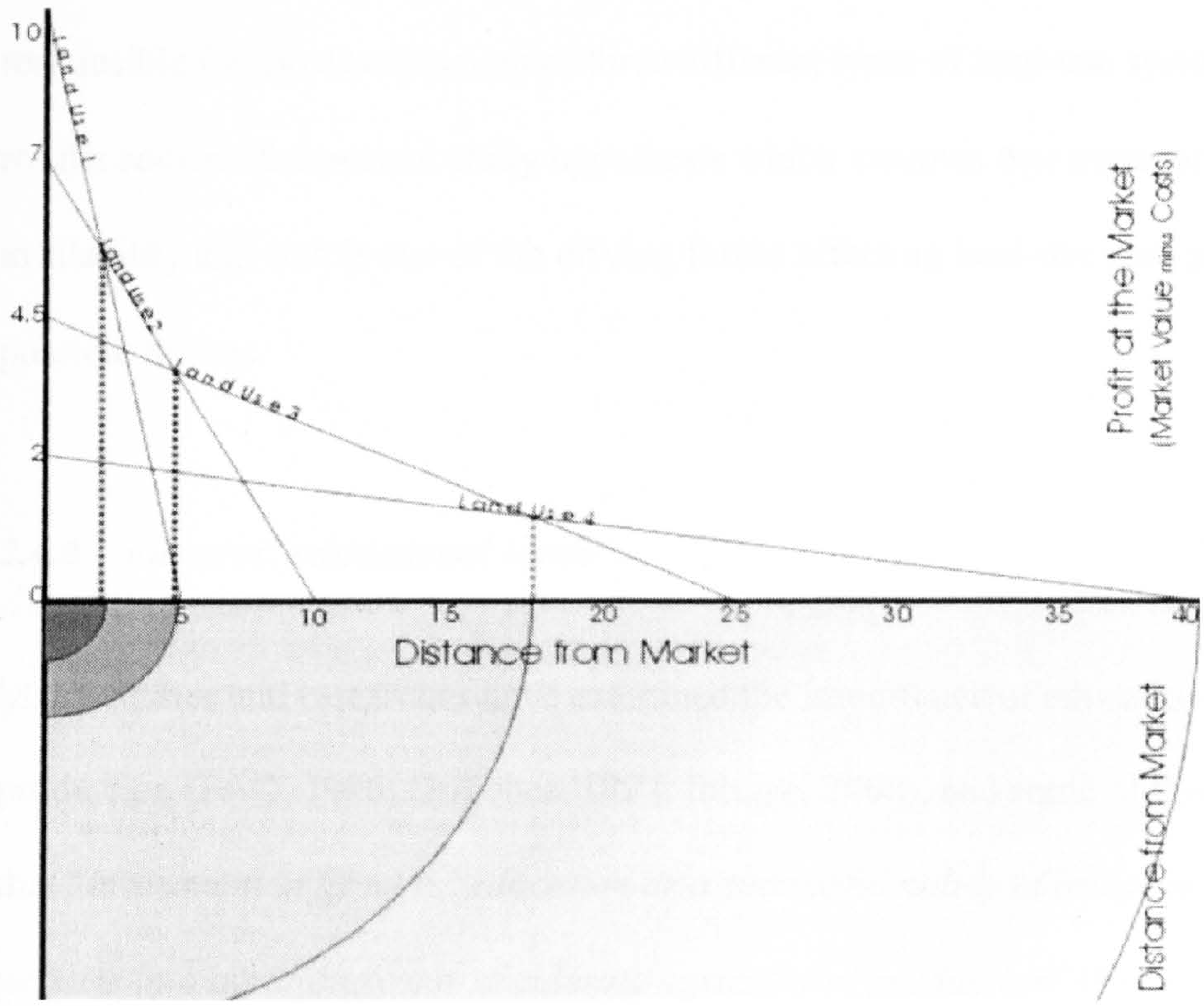


Figure 2.4: Balancing land-use practices and transportation costs using Von Thunen's land-use model (Source: Crosier, 2006)

Although some critics argue that this model is no longer valid because it does not take into account additional variables such as farmers' behaviour and aspirations, agricultural policies and physical characteristics. Other researchers confirm, however, that this model is an attempt to represent a theoretical understanding of land-use patterns and the effect of transportation cost. This model could be modified to include other factors and could offer an explanation for contemporary land-use patterns in villages and farms in some developing countries (Robinson, 2004). A field study carried out by Rasul *et al.* (2004) in a developing country (Bangladesh) investigating determinants of land-use changes concluded that distance to the market and service centre, institutional support, and productive resource base were the main factors responsible for the development of three different types of land-use systems. These results confirm the present study hypothesis which assumes that transportation availability and cost is one of the driving forces affecting land-use change among other possible drivers.

2.4.6 Farmers' educational levels

Many studies and researches have examined the importance of education in agricultural production (FAO, 1996; Griliches, 1997; Ibitayo, 2006), and some of them concluded that "*investment in farmers' education or a successful policy of bringing educated persons into agriculture can accelerate agricultural production*" (FAO, 1996: 1). Education can be defined as "*the process by which an individual is encouraged and enabled to develop his or her potential; it may also serve the purpose of equipping the individual with what is necessary to be a productive member of society*" (Wikipedia web site, 2006). The term is often used to refer to formal education. However, the word's broader meaning covers a range of experiences, from formal learning to the building of understanding and knowledge through day to day experiences. Ultimately, all experiences serve as a form of education. Individuals receive informal education from a variety of sources. Family members, peers, books and mass media have a strong influence on the informal education of the individual. Such is the fundamental role of education and training that the FAO has mentioned that without them most development interventions will be ineffective. Therefore, the FAO Human Resource Development Department focuses on a series of actions directed at helping participants in the development process to increase their knowledge, skills and understandings and to develop the attitudes needed to bring about the desired developmental change (Sustainable Development Department, FAO, 1996).

Pudasaini (1983), utilizing a production function framework, reported that there was a higher return on education in terms of agricultural productivity in a modernizing environment than in traditional agriculture. Higher (college) education had a significant role in a modernizing environment but not in the traditional area. In another widely acknowledged study conducted by Lockheed *et al.* (1980), and as a testimony of the general consensus that education has a positive effect on agricultural productivity, they presented a survey investigating the effect of farmers' educational level on farm efficiency in less developed countries. They concluded that, on average, 4 years of schooling resulted in a 7.4% improvement in output, giving a measure of evidence to support conventional wisdom (Lockheed *et al.*, 1980). These results have also been confirmed by Philips (1994) as well as additional studies since the Lockheed *et al.* survey and will form an important component of the present study (see Section 2.6)

2.4.7 Rural women and their contribution in agriculture

There is a widespread agreement that rural women in developing countries play an important role in household food security and agricultural production (Kaur and Sharma, 1991; Rahman, 2000). It is generally agreed that women produce between 60 and 80 per cent of the food in most developing countries and are responsible for half of the world's food production (FAO, 1995). Rural women in developing countries are also responsible for gathering food, fodder and fuel wood, and for drawing water and managing the domestic water supply (Al-Rousan, 2005). In sub-Saharan Africa for example, women are responsible for producing and marketing over 75 per cent of food, and they are in charge of more than 80 per cent of domestic food processing and storage, 70 per cent of hoeing and weeding, 60 per cent of harvesting and marketing, 50 per cent of livestock care and crop planting, and 30 per cent of ploughing. This is in addition to undertaking 95 per cent of housework, including the collection of water and fuel wood (Atkins and Bowler, 2001; Robinson, 2004). Women in developing countries, particularly from rural poorer households, are trying to keep the balance of their multiple demands of labour time between their economic role (wage earning and income-replacing work such as of fuel wood and water collection, care of livestock) and domestic duties (cooking, cleaning and child care) by working longer hours than men (Kabeer, 1994). In several parts of the third world, rural women make a critical contribution to food security, agricultural production and environmental resources management. For instance, rural women in Bangladesh have played an important role in a wide range of income-generating activities. These rural production activities include post-harvesting, cow fattening and milking, goat farming, backyard poultry rearing, horticulture and food processing (FAO, 2005b). A study by the World Bank (1991) suggested that approximately 84 per cent of all economically active women are involved in agriculture in India with a positive correlation between agricultural growth rates and employment of female agricultural labour (World Bank, 1991). In Sri Lanka, the crucial role of women in environmental resource management has inspired Wickramasinghe (1997: 14) to describe them as "*the silent managers of the environmental resources of the village ecosystem*". In addition, they work longer hours than men especially when other household activities are included. During the farming off-season, when about 50-60 per cent of men migrate to cities for off-farm employment, women tend to spend their time in gathering and producing crops for family consumption (Wickramasinghe, 1997). Rural women in Egypt have also played a crucial role in food security and agricultural production. Surveys showed that the majority of rural women in Egypt participate in agricultural activities, particularly those related to food security and animal production. More than 50% of rural women in Egypt are actively involved in tasks such as applying fertilisers, weeding, harvesting, sacking, marketing and storage. Some also undertake ploughing and irrigation. About 70% of their working time in agriculture is devoted to animal husbandry (Alozabie, 1997; Ahmed, 1999). Yet, these vital roles of women in farming, agricultural production and food security are often overlooked and women's work in agriculture has often been invisible. This is partly due to statistics which often do not reflect the true contribution of women in farming activities and within the household, because these statistics exclude women's subsistence production and domestic work (Kabeer, 1994; Robinson, 2004). Other problems encountered in the contribution of rural women in farming practices and agricultural production are that rural women tend to be unskilled, have limited or even no educational level, lack access to land, are hampered with household responsibilities, and without access to credit facilities (Atkins and Bowler, 2001). In order to have a chance to succeed, rural women need to be targeted by training programs and agricultural extension services. Thus, the role of rural women in agricultural production and land-use change will be investigated in this study (see Section 2.6).

2.4.8 *Agricultural subsidies*

As one of the possible economic driving forces affecting land-use change, agricultural subsidies in both developed and developing countries represent government policies that benefit the agricultural sector of the economy (Harik, 1992). Agricultural policies influence land-use decision making by altering prices, taxes, and subsidies on land-use inputs and products, changing the costs of production and transportation, and by altering capital flows and investments, credit access, trade, and technology (Barbier, 1997; Lambin and Geist, 2006). A common feature is an economic transfer, usually in direct cash form, from governments to farmers. These transfers can aim to reduce the costs of production in the form of an input subsidy such as fertilisers or pesticides, or to make up the difference between the actual market price for farm output and a higher guaranteed price (Tiwari and Dinar, 2001, Lingard, 2002). In an attempt to discuss how agricultural subsidies influence land-use change, Lingard (2002) suggested that input price subsidies and output price subsidies will promote intensification of production processes. Subsidies will increase the use of variable production inputs, such as fertiliser, irrigation water, pesticides and herbicides; they will change the optimal combination or factor proportions with which inputs are used, and output price subsidies will lead farmers to substitute one crop for another or change between crop production and livestock production processes (Lingard, 2002).

Based on the discussion presented above, the present study will examine the role of agricultural subsidies (governmental and from private sector) in affecting land-use change later in Chapter 6. After the previous argument and discussion about possible driving forces that affect land-use change at the local level, an explanation of pressures, impacts, state and responses in the context of the DPSIR framework will be presented next.

2.4.9 Pressures, State, Impacts and Responses of land-use change

The discussion above has shown that various land-use change studies have approached the investigation of driving forces from different perspectives and that their relative importance in a given area varies according to the scale of interest. A number of driving forces described above that affect land-use change at the local level will be analysed and tested in Chapter 6. This section, however, will focus on the explanation of pressures, state of environment, impacts and responses of land-use change.

Pressures on land-use have been described by many researches and studies as the causes of problems derived from driving forces (Lambin *et al.*, 2003; Bach, 2004). Each driver will create many pressures. For example the increase of population density will put more pressure on the resources use, labour availability and quantity of resources.

Ultimately, this increase will lead to more agricultural land converted to residential and industrial areas to accommodate the increased number of population. *The state of land-use* refers to changes in environmental conditions that may arise from various driving forces. It is, therefore, the structure and functioning of existing components of land-use in the studied area (crop patterns, water surface, and other land uses), in addition to full description of other natural resources such as quality of water and soil and their characteristics, that will also be important. *Impacts on land-use* refer to changes that occur in the environment and people which lead the society to response. These changes could be resulting from human induced modification to the physical and socio-economic structure of land-use characteristics or due to ecological effects. Although it is possible to divide the impacts on land-use in a given study area into two main categories -biodiversity loss and economic damage- the other impacts still exist such as desertification, reduced crop productivity, degradation of soils, and increased prices for farming commodities. *Responses of land-use change*, meanwhile, relate to actions taken by society either individually or collectively (EEA, 2001; Svarstad *et al.,* 2008). These actions or events are designed to prevent negative environmental impacts from existing damage, or to conserve natural resources. These responses may include regulatory action, environmental or research expenditure, public opinion and consumer preference, and changes in management strategies. Responses should be designed to act and feedback on driving forces, pressures, state, and impacts.

2.5 The DPSIR framework

As mentioned in Chapter 1 and Section 2.3 of this chapter, a considerable number of studies have presented different methods and frameworks for understanding the cause-effect relationship between land-use change (biophysical and/or socio-economic) and the consequences resulting from this change (Turner II *et al.*, 1995; Verburg *et al.*, 1999; Campbell *et al.*, 2003). These models and frameworks have tried to deal with the interactions between socio-economic and biophysical driving forces at different spatial and temporal scales. Recent publications and studies have showed that the land-use change science community has successfully met this challenge and a wide range of advanced models, aiming at different scales and research questions, are now available (Verburg *et al.*, 1999; Briassoulis, 2000, Agarwal *et al.*, 2002; Parker *et al.*, 2003; Nagendra *et al.*, 2004; Verburg and Veldkamp, 2005; Lambin and Geist, 2006).

One of the most important observations that can be made examining the range of available land-use change models and frameworks is the wide diversity of approaches and concepts underlying land-use change models (Verburg *et al.*, 2006; Lambin and Geist, 2006). One of these conceptual frameworks is the DPSIR (Driving forces, Pressure, State, Impact, and Response) conceptual framework. As mentioned in Chapter 1, the DPSIR framework will act as the conceptual framework for analysis of land-use change in the present study.

The first form of the current DPSIR framework was the *Stress-Response* framework developed by two scientists working at Statistics Canada (Rapport and Friend, 1979).

Their *Stress-Response* framework was based on ecosystem behaviour; they distinguished between environmental stress (pressures on the ecosystem), the state of the ecosystem, and the ecosystem response. When the *Stress-Response* framework was presented to the Organisation for Economic Co-operation and Development (OECD), the ecosystem response was removed in order to make the concept suitable for the approach used by OECD. The rephrasing of "response" to mean societal response only, led to the OECD Pressure -State- Response (PSR) model (OECD, 1991; Bowen and Riley, 2003)). However in the early 1990s, and because environmental statisticians dealt not only with data on pressures, state and responses, but also with their origins in economic activities, the European Environment Agency (EEA), the United Nations and the European Commission developed the PSR framework to include *driving forces* and *impacts* components. The final form of the DPSIR framework described human activities and physical drivers, pressures, state of the environment, impacts on ecosystems, human health and materials, and responses (EEA, 1995). The EEA helped to make this final DPSIR framework more widely known in Europe and this model has become the main framework for EEA assessments and related activities.

There have been different views among researchers, particularly in developed countries, about the development of models within the DPSIR framework. Some authors have argued that the need to understand better the linkages and interactions of socio-economic and biophysical causes and consequences of land-use change has taken on a more deliberate role in the development and assessment of different types of models and frameworks designed to investigate land-use change world-wide (Imeson, 2001; Vazquez, 2003). Others have suggested that the analysis and establishment of indicator-driven frameworks to assess changes in land-use and other environmental problems in a given area have increasingly moved to concentrate on socio-economic driving forces and impacts. Therefore, the development of the DPSIR framework, as an integrated model taking into account the socio-economic and physical drivers interactions, is now in broad use and provides an essential contribution in the assessment of environmental problems and land-use change studies (Bowen and Riley,2003; Kremer *et al.,* 2005).

Enne and Zucca (2002) and Imeson (2005) have emphasised that the DPSIR framework was chosen to be the conceptual framework for DESERTLINKS project in the assessment of desertification process in Mediterranean Europe, because it seemed to be the most comprehensive amongst those designed to describe interactions existing between the components of the natural and socio-economic system. Vacik *et al.* (2005) meanwhile, suggested that the DPSIR framework seems highly capable of showing information in an analytical, causal way when differentiating between causes, effects and human measures and responses to control the damage resulting from pressure and amount of negative impacts on society and individuals. However, Olson *et al.* (2004) argued that the DPSIR framework suggests a linear, unidirectional causal chain and does not include the interactions between variables within boxes. It provides a logical framework for illustrating assumed factors, but it is not based on socio-economic or ecological theories or concepts, and so provides little assistance in the initial identification of the critical variables, their relationships, or how they relate to the problem and its possible solution.

Applications of the DPSIR framework have varied among studies and authors over time. In its earlier form, it was widely accepted and commonly used for interdisciplinary indicator development and the structuring of integrated research programmes and assessments. For example, the European Environment Agency used the DPSIR framework in its inventory of biodiversity to identify more than 600 indicators in Europe. These indicators have been subdivided into the following categories; nature protection, forestry, energy, recreation/tourism, climate change, urban development, rural development, water, infrastructure/transport, trade, fisheries, and agriculture (EEA, 2003a). Today, however, the DPSIR framework is increasingly used as a conceptual framework for structuring case studies in relation to issues of human interferences with environmental problems and efforts to address land-use change in different areas and scales (Elliott, 2002; La Jeunesse *et al.*, 2003; Scheren *et al.*, 2004; Holman *et al.*, 2005; Hasse *et al.*, 2007). A large number of studies and authors who assessed the application of the DPSIR framework have acknowledged the advantages of using this model in the assessment of land-use change and other environmental issues. For example, Zalidis *et al.* (2004) argued that "*for practical purposes, the PSR (Pressure, state and response) model is sufficient. However, for both compatibility reasons and a more thorough description of underlying economic trends, the DPSIR model permits better incorporation of non-environmental variables*" (Zalidis *et al.*, 2004: 316). The European Environment Agency (EEA) has extensively used the DPSIR conceptual framework to support sustainable development and help achieve significant and measurable improvement in Europe's environment (EEA, 1999; EEA, 2003). Giupponi *et al.*, (2004), meanwhile, suggested that "*the DPSIR framework aims at illustrating the* *cause–effect relationship between interacting components of complex social, economic and environmental systems and at organising the information flows in different systems of human activity*" (Giupponi *et al.*, 2004: 17), an assertion also supported by Macleod *et al.* (2007: 599) who argued that "*the advantage of the DPSIR framework is that it structures the user's thinking to understand the whole picture and dynamics of the system*". This argument and discussion about the suitability of the DPSIR framework for communicating policy-relevant results between researchers and other stakeholders attempting to understand and use the DPSIR framework has been the key issue for discussion among researchers from different parts of the world. In particular, the lack of studies and investigations using DPSIR as a main framework to address environmental issues or interaction between the state of environment and human activities in developing countries has been addressed as an acute gap which needs to be studied and investigated. A clear example (as mentioned in Chapter 1) was the workshop held in Adana, Turkey in 2003 where contributors concluded that the DPSIR could form a useful framework for better understanding land-use changes in arid and semi-arid areas of the developing world (Zdruli *et al.*, 2003). The need for the DPSIR framework application in developing countries especially at the rural-urban fringe has been elaborated further by Fujiwara *et al.* (2005) when they suggested that DPSIR as a data-driven approach is widely applied to sustainable development problems and they applied this model in a study in order to capture complex cause-effect relationships existing in the measurement of the sustainability of urban development over time in a developing country.

There seems to be some consensus, therefore, that DPSIR can act as a suitable analytical framework to address land-use change issues in many different geographical contexts. However, results from the above discussion and argument and the different calls from researchers in developing countries have highlighted the need for further examinations of the application of the DPSIR framework in arid and semi-arid areas of the developing world. These criteria actually form the rationale for the focus of the present study.

2.6 Conclusions

This chapter presented the major theories about land-use change and reviewed key studies which provided a foundation for this research on land-use change in the Nile Delta. Contrasting conceptual frameworks were described and some of their applications were given. A key element of the chapter was the discussion of the components of the DPSIR framework; driving forces, pressures, state of land-use, impacts and responses. An assessment of the role of globalisation and the World Trade Organisation in affecting land-use was presented in this chapter. The need for more studies of land-use change in arid and semi-arid regions of developing countries was also explained.

As mentioned in Section 2.4 of this chapter, land-use change has been influenced by interaction between different types of driving forces including biophysical, social, economic and cultural factors. There has been no agreement among authors involved in land-use change studies that causes of land-use change are identical in different geographical areas and at various scales. Based on the discussion and argument presented in Section 2.4 of this chapter, this thesis has the following hypotheses:

Null hypothesis one: There is no significant relationship between land-use change and the biophysical driving forces such as the need for irrigation water, use of fertiliser and use of pesticide in the study areas.

Null hypothesis two: There is no significant relationship between land-use change and the economic driving forces such as transportation availability and cost and agricultural subsidy in the study areas.

Null hypothesis three: There is no significant relationship between land-use change and the social and cultural driving forces such as population growth, farmers' educational level and rural women's contribution in agricultural production in the study areas.

Having stated the hypotheses of the present study, the next chapter will discuss and explain the research methodology adopted for this thesis.

Chapter 3: Research Methodology

3.1 Introduction

Chapters 1 and 2 provided a theoretical understanding of land-use change. The various studies adopted a range of methods and frameworks to achieve their objectives. The empirical techniques used in land-use change studies varied according to the aim of study and research questions investigated. As an introduction to the practical part of this thesis, this chapter reviews, first, the methods used to collect and analyse data and, second, the implementation of this study's conceptual framework to organise and explain the results. Earlier research which investigated land-use change has followed a number of different methodological approaches depending on the type of geographical phenomenon under investigation and especially whether it is focused on more physical or human geography aspects.

Physical geographers, for instance, have tended to adopt quantitative methods to classify land-use patterns and identify the causes behind land-use changes (e.g. Andersen, 1996; Mertens and Lambin, 1997; White *et al.*, 1997). These methods incorporate explanatory variables that can be obtained from remote sensing data and calculated using Geographical Information Systems (GIS), such as distance measures, other spatial biophysical variables (e.g. soil, slope and elevation), and occasionally socio-economic variables, such as population or gross domestic product measures (Tomich *et al.*, 2004; Reger *et al.*, 2007). In many cases, these methods provide the basis for understanding spatial processes and land-use change consequences reasonably well. However, they are less successful at explaining the human behaviour that leads to the spatial process or the impacts of land-use change.

Human geographers, meanwhile, have a tendency to investigate land-use change by applying both qualitative and quantitative methods (Shao *et al.,* 2005; Weber *et al.,* 2007). These methods take into account features that affect choice concerning land-use change. Important features might be characteristics of the individual land managers or farmers such as family size, off-farm income, distance to markets (transportation cost), educational levels, gender role and other farming practices (Irwin and Geoghegan, 2001). In addition, several geographical studies on land-use change have incorporated both biophysical and socio-economic drivers and therefore applied both quantitative and qualitative methods in the analysis of land-use change (Pax-Lenney *et al.,* 1996; Veldkamp *et al.,* 2001; Seto *et al.,* 2002; Millington *et al.,* 2007).

One of the main aims of this thesis, identified in Chapter 1, is to examine the application of the DPSIR framework for better understanding of agricultural land-use change in the rural-urban fringe in the Nile Delta of Egypt. To achieve this aim, both quantitative and qualitative techniques will be used. Clifford and Valentine (2004:7) suggested that *"there is no set recipe for choosing the most appropriate method(s): different methods have particular strengths and collect different forms of empirical material. The most appropriate method(s) for your research will therefore depend on the questions you want to ask and the sort of information you want to generate".*
In this context, it is important to distinguish between two types of research methods; deductive and inductive. Germov and Poole (2007) highlighted the differences between deductive and inductive approaches to research. They argued that deductive researchers develop research questions, and ask questions about the ways in which variables are

related. Using deductive techniques, investigators start with a particular theoretical perspective and review the previous research that examines that particular theory. Based on this approach, they develop hypotheses and test these hypotheses. The aim of testing these hypotheses is to interpret the research findings in the context of the theory and literature on which the hypotheses were based. On the other hand, Creswell (2003) suggested that inductive research begins with data collection, and on the basis of these data the researchers make an observation about the phenomenon under investigation and then compare this observation with other results, and eventually this leads to the generation of a theory. The present study will follow the deductive approach to investigate land-use change in the eastern part of the Nile Delta.

In the development of analytical research methods for this study, it must be stressed that it is possible to combine a range of different types of methods. This process of drawing on different methods is known as triangulation (Clifford and Valentine, 2004). From the above discussion, this study will follow a two-stage strategy. First, starting with the research questions and aims of this research, methods will be developed to achieve the aims identified in Chapter 1. Second, a "multi-method" approach will be used as a way of cross-checking and triangulation.

There are two main sources of data used in this thesis: primary data which consisted of remote sensing data, questionnaire data, interviews, and participant observation. Remote sensing data will be used to investigate land-use and cover change in the research region (including the two study areas, see Section 3.4.1), while the questionnaire data and participant observation will provide the basis for deeper investigation and evidence of land-use change on the ground. Interviewing agricultural experts in the two study areas will provide additional valuable information on land-use change drivers. Secondary data, meanwhile, will be obtained from census data and complement primary sources. The methodology described in this chapter is organised accordingly:

- In Section 3.2, the spatial scale of investigation will be explained. This will include a discussion of the case study approach in general and its application in this thesis. The rationale for selecting Egypt as a case study country will be presented. In addition, justification and criteria for selecting the two study areas in the Nile Delta are addressed.
- Section 3.3 presents justification for the selection of the time scale for the study (the last two decades).
- Section 3.4 will review research methods used in the case study areas. Specific emphasis will be placed on remote sensing data and the types of classification. The questionnaire design, coding and the statistical software used for data analysis will be presented. This section will also present a review of interviews with expert people and farmers in the two study areas. Further, participant observation and the census data used in the analysis will be explained.
- In Section 3.5, the DPSIR model will be discussed as a method used in this thesis to organise and analyse the indicators which represent the five components of the framework and data collection tool used for each associated indicator.

Table 3.1 sets up the methodological framework for this study; this study is conducted in one research region containing two contrasting study areas in the eastern part of the Nile Delta. The spatial scale of the research region is 60 × 60 km, and the temporal scale is between 1984 -2003 (see Sections 3.2 and 3.3). The table also shows that the total number of selected farms investigated in both case study areas is 180 farms (see

Section 3.4.2 for more detail). It can be seen from the table that, at the level of research region investigation, the focus is on land-use and cover change using remote sensing data. In the meantime, at the interface between farm and local level in the rural-urban fringe, the main concern is to provide evidence of land-use change using remote sensing data, questionnaire data, and information collected from interviewing agricultural experts and farmers in the two study areas. Finally, the table shows that the DPSIR framework has been used to organise and describe the relationships between factors affecting land-use change using questionnaire data and information collected from interviewing farmers from the two case study areas. The most appropriate spatial scale for data collection and investigation, as shown in Table 3.1, will be discussed in Section 3.2.

Spatial Scale	*N**	*Temporal scale*	*Area of focus*	*Data used (Technique)*
Research region (60 by 60 km)	1	1984-2003	Land-use and cover change	Remote sensing data
Study area (20 by 20 km)	2	1984-2003	Evidence of land-use change	Remote sensing data Census data Questionnaire data Interviews (experts and farmers)
Selected farms (Up to 20 Feddans**)	180	1984-2003	DPSIR framework	Questionnaire data Farmers interviews

Table 3.1: Case study region and the two study areas used in this thesis

** N= number of cases*

*** 1 Feddan = 0.42 Hectare*

3.2 The spatial scale of investigation

This section identifies and justifies the appropriate spatial scale for land-use change analysis in the two study areas. It also discusses the case study approach in a general context and in terms of this study's application. The section then addresses the rationale for selecting the Nile Delta of Egypt as a study region. Finally, the reasons for the selection of the two case study areas in the eastern part of the Nile Delta are presented.

3.2.1 Selecting the appropriate scale for analysis: the "farm" and "local scale" interface

The importance of the issue of spatial scale in the analysis of land-use change has been outlined on several occasions in this thesis (see Chapter 2, Turner II *et al.,* 1995; Lambin *et al.,* 2000; Veldkamp *et al.,* 2001). Briassoulis (2000) argued that one of the most important issues in any study of land-use change is the level of scale at which the measurement is conducted, spatial and temporal scale primarily, but also social, economic, institutional and cultural scale. Lambin (2004) in particular, argued that the spatial scale at which land-use changes are modelled affects the type of explanation given to land-use change. At national or global scales, the high level of data aggregation could obscure the variability of situations and relationships, and gives sometimes irrelevant results because key variables are lost by averages. On the other hand, the development of very detailed scale models for every local situation will be impractical and inadequate if there is no possibility of generalising these models. Therefore, a hierarchical approach will be adopted in both the observation and explanation of land-use change processes (Figure 3.1).

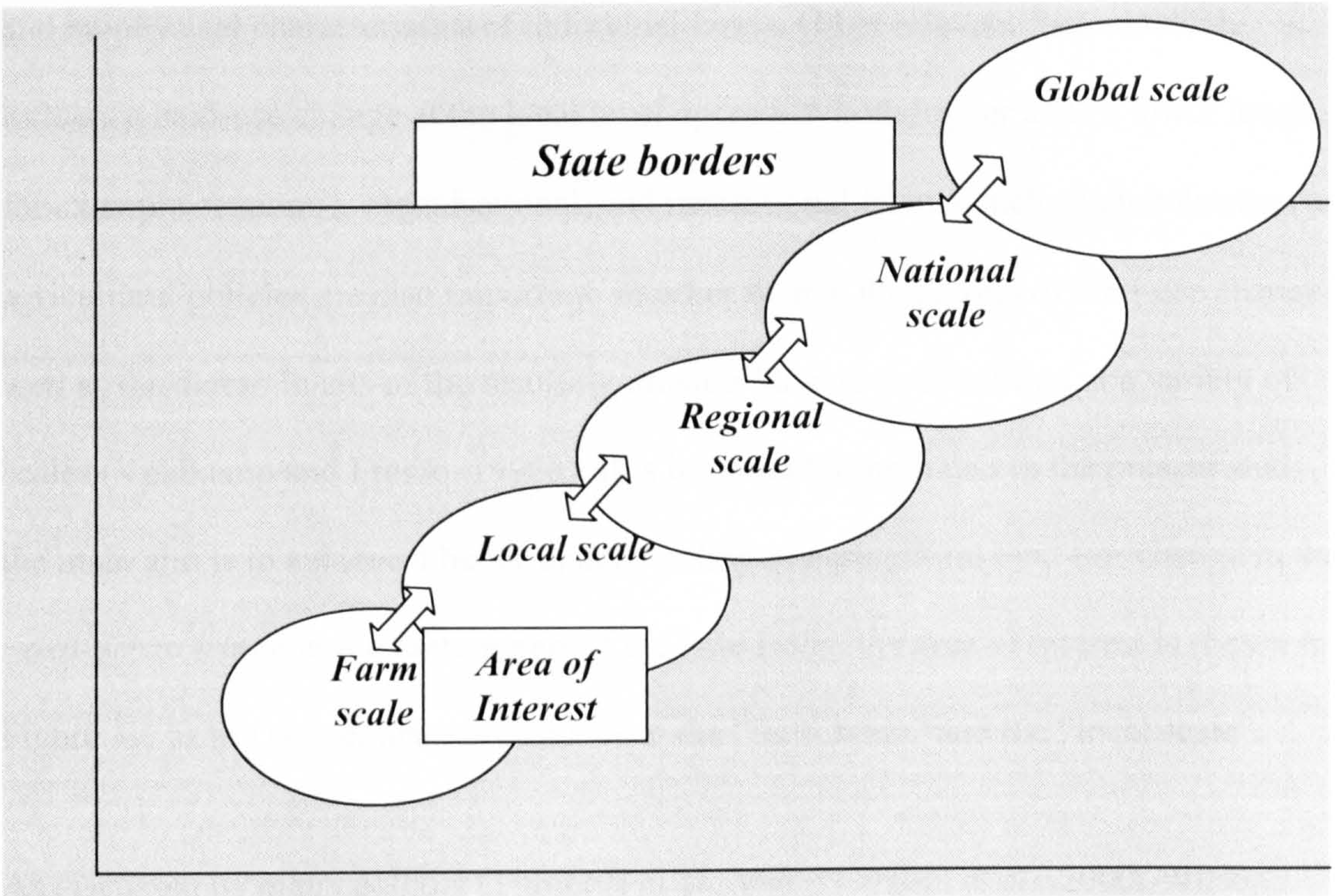


Figure 3.1: The spatial scale area of this study (Source: adapted from Wilson, 2007)

Verburg *et al.* (2004a) emphasised that explanation of land-use change is related to the spatial scale at which the analysis is conducted. Therefore, understanding land-use change (and its impacts) at any scale requires that the relevant explanatory driving forces are identified at the level of the particular (and of other relevant levels) scale at which they are influencing land-use change. The critical point is that "the relevant explanatory drivers", with the exception of the biophysical determinants, are associated with particular individual and group actors or agents involved directly or indirectly in the process of land-use change. Essential explanation focuses on these agents who influence land-use change, and their actions through which land-use change is affected.

There is, therefore, a need to employ a nested set of scales for a comprehensive explanation of land-use change in particular settings (Figure 3.1). At the scale of selected farms (i.e. local scale), important characteristics include the socio-economic and biophysical characteristics of individual farms. Other relevant factors which influence land-use change at the local level operate at both higher and/or lower levels, for example economic, organisational, and institutional factors such as globalisation and agricultural policies are also important. In other words, the drivers of land-use change as well as the determinants of the resulting impacts have to be identified at a variety of scales (Veldkamp and Fresso, 1996b). It is important to note that in the present study, as the main aim is to achieve a better understanding of agricultural land-use change in the *rural-urban fringe* in the eastern part of the Nile Delta, the area of interest is shown in Figure 3.1 as the conceptual space between the "farm scale" and the "local scale".

As discussed by many authors (Turner II *et al.,* 1995; Lambin *et al.,* 2000; Wilson, 2007), land managers (farmers) - at the farm level- play a decisive role in farming decision-making. For this reason, any land-use change study at a local level should take into account farmers' behaviour and aspirations associated with their social, cultural and economic characteristics affecting land-use change at the local scale. In addition, land-use change can only be understood with reference to scales above and below those of interest. This assertion leads to consideration of the importance of other drivers affecting land-use change at the regional, national and global level. For example, the identification of driving forces affecting land-use change and assessment of the consequences at the local level has to consider the role of other drivers that operate at national and global levels, such as agricultural policy, climate change, globalisation and the WTO.

The next step after identifying the spatial scale of investigation is to discuss the methods used to conduct land-use change analysis and the justifications for the case study approach adopted in this study.

3.2.2 Approaches for the selection of a case study region and case study areas

The research addressed in this thesis has adopted a case study approach (see Table 3.1 above) as a key methodological step. The case study approach has been used as a common research strategy in different fields of science, especially in social and political sciences, business studies, economics, and planning (Yin, 1994; Stake, 1995). The importance of using the case study approach comes from its unique contribution to understanding information about individual, organizational, social, and political events and from the desire to understand complex social and natural phenomena. Not surprisingly, the case study has been described by Yin (1994:3) as an approach that "*allows an investigation to retain the holistic and meaningful characteristics of real-life events such as individual life cycles, organisational and managerial processes, neighbourhood change, international relations, and the maturation of industries*".

Yin (1994) identified five components of research design that are important for case studies. These components are: research questions, research propositions (if any), the unit(s) of analysis, the logic linking the data to the propositions, and the criteria for interpreting the findings. The research questions in any case study investigation are most likely to be appropriate for the "how" and "why" type of questions and their definition is the first task of the researcher. The research propositions sometimes derive from the "how" and "why" questions, and can be helpful in focusing on the research aims. Although not all studies need to have propositions, an exploratory study, rather than having propositions, may have a stated purpose or criteria on which the success will be judged. The unit of analysis defines what the case study is. This could be individuals, groups, organizations or countries, but it is the primary unit of analysis.

Case studies have been used as practical methodological tools for three types of research (Figure 3.2); *descriptive*, *exploratory*, and *explanatory* (Yin, 1994; Creswell, 2003). Fisher and Ziviani (2004) argued that *descriptive* case studies usually describe interventions or demonstrate certain topics. This type of case study is usually considered less demanding than an explanatory one and no causal links need to be made. In *exploratory* case studies, fieldwork and data collection may be carried out prior to definition of the research questions and hypotheses (Brown *et al.*, 2000; Aspinall, 2004). *Explanatory* case study approaches are suitable for conducting research aiming at explaining causal relationships (Bergeron and Pender, 1999, Verburg *et al.*, 2004b).

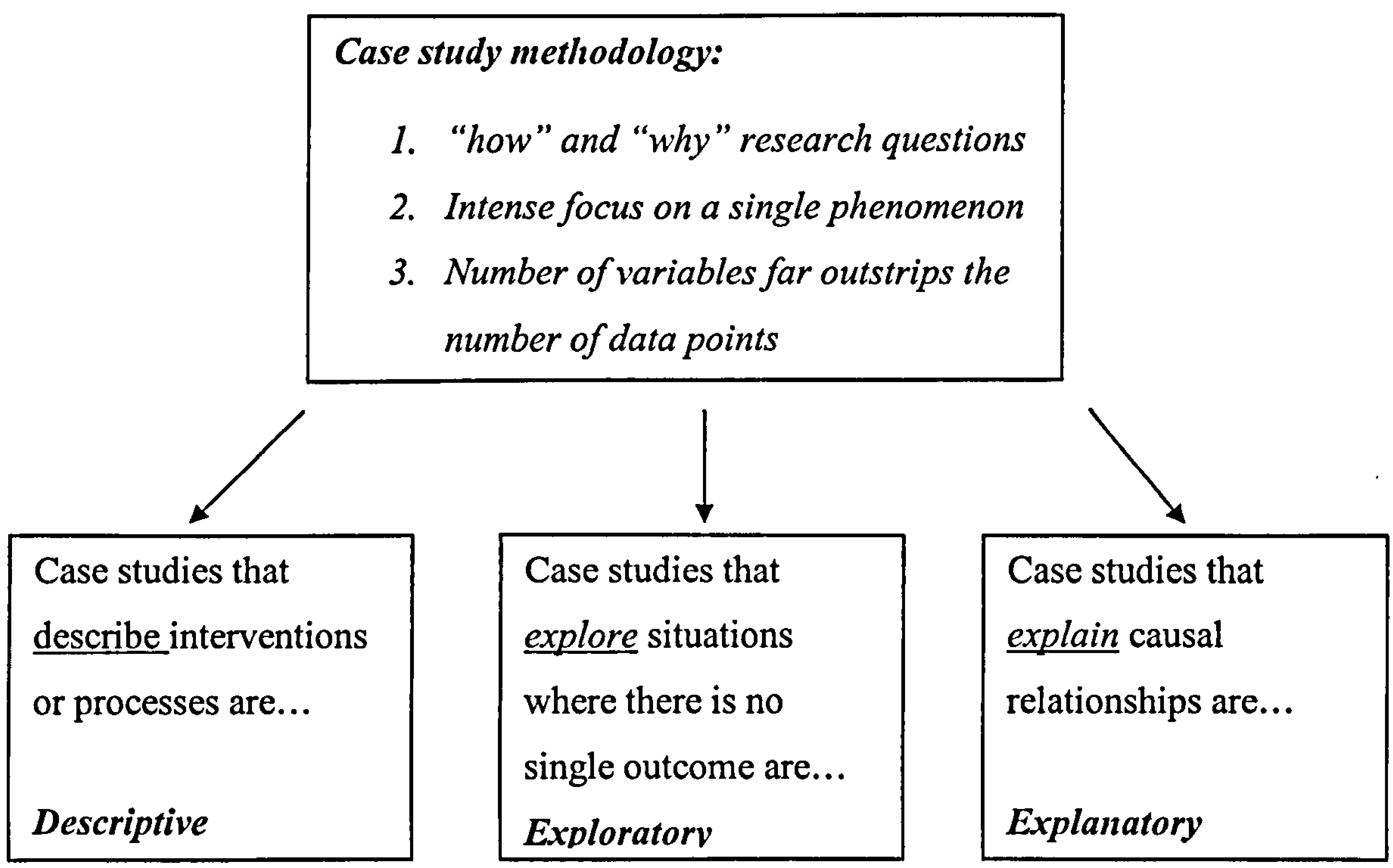


Figure 3.2: Types of case study methodology (source: Fisher and Ziviani, 2004)

The importance of using a case study approach in land-use change investigation has been advocated in recent years by several international study groups on land-use and land cover change. For example, the International Geographical Union (IGU), the

International Geosphere–Biosphere Programme (IGBP), and the International Human Dimensions Programme (IHDP) all emphasised that the use of case studies as a methodological approach in land-use change investigation can significantly improve the understanding of the major human causes of land-use and land-cover change in different geographical and historical contexts (Gardner *et al.,* 1999; Schoorl and Veldkamp, 2001; Odermatt, 2004; Xu, 2004).

A few examples may illustrate how land-use change studies have used the case study approach. Chen *et al.,* (2007) for example, have used a case study methodology to compare quantitative and qualitative changes of cultivated land in two regions (Fujian and Taiwan). The authors concluded that comparative case studies have been helpful tools to analyse the proximate causes and the driving forces for land-use changes over time. Their case study investigation also showed a time lag, similar to that of economic development, in the dynamic (i.e. greater rates of change) period of cultivated land-use changes and the ranking of major driving forces. Further, in a land-use change study aimed at achieving a general understanding of the proximate causes and underlying driving forces of tropical deforestation in contrasting regions, Geist and Lambin (2002) emphasised the importance of using case studies when comparing different regions.

The ability of the case study approach to utilise different types of data and information resources (cross-checking), and the nature of research questions and aims identified earlier in Chapter 1, have formed the basis for the present study to consider the case study approach as a methodological tool for investigating land-use change. For the purpose of this study, the eastern part of the Nile Delta of Egypt has been selected as the research region containing two case study areas. The rationale and justification for selecting the two case study areas in the Nile Delta of Egypt will be discussed in the following section.

3.2.3 The rationale for selecting the Nile Delta of Egypt as a case study region

As discussed in Chapters 1 and 2, this study focuses on the investigation of land-use change in arid and semi-arid areas in a developing country. The importance of understanding land-use change in such areas was outlined in these two chapters. In this section, the rationale for selecting the eastern part of the Nile Delta of Egypt as the research region will be discussed followed by justifications and reasons for selecting two case study areas within this region (Section 3.2.4).

One of the initial objectives in developing the empirical research in this thesis is the selection of a suitable research region in which to investigate agricultural land-use change. Considering the central aim of this study in understanding land-use change in the rural-urban fringe of arid and semi-arid areas in the developing world, the study had to take into consideration a specific area in a country which experiences changes and variation in types of land-use and land-cover. The Nile Delta of Egypt was selected for four main reasons. First, the Nile Delta has a semi-arid climate with two main seasons: hot dry summer and cool dry winter. The average annual air temperature is 20.7° C and precipitation is 38 mm per year (Aboelghar *et al.,* 2004; see Chapter 4 for more details). Second, the Nile Delta is of extremely high agricultural value and comprises one of the oldest intensely cultivated areas of the world. It contains different types of land-cover and land-use (Aboelghar *et al.,* 2004):

1- Old agricultural land with traditional irrigation system (surface irrigation) and cultivated with annual crops, fruits and vegetables grown during two main agricultural seasons.
2- Recently reclaimed areas with circular irrigation systems (central pivot) and cultivated with different types of crops.
3- Old reclaimed areas that are cultivated extensively using traditional irrigation methods (surface irrigation).
4- Water bodies and wetlands.
5- Desert lands that have not been included in any reclamation effort.

A third reason is that the problem of land-use change is compounded because more than 95 per cent of Egypt's population (75 million) is concentrated around the River Nile and the Nile Delta. In addition, the steadily increasing population (see Chapter 4) causes serious socio-economic problems and increasing pressure on fragile agricultural land. This has caused a decrease in area per capita: 0.20 ha in 1907; 0.12 ha in 1950; 0.06 ha in 1990 and 0.05 in 2004 (Belal, 2006; Shalaby and Tateishi, 2007) as well as a loss of productive agricultural land estimated to be at a rate of 13,000 hectares per year (Arafat, 2003). Therefore, land-use patterns are constantly changing, often with agricultural land converted to urban use and desert areas converted to farmland. In addition, Aboelghar and Tateishi (2002) concluded in their land-cover investigation that the eastern part of the Nile Delta has been one of the most dynamic and rapidly changing areas in Egypt for the last two decades.

Finally, in addition to my experience of agriculture in Syria, my knowledge and background about the area (e.g. Arabic language, cultural and personal links) gained during my Masters Degree period in Egypt was also an important reason for selecting the Nile Delta of Egypt as a case study area for land-use change investigation in this thesis. In particular, this background enabled me to obtain the required data through the questionnaire directly from farmers and to conduct interviews with local agricultural experts in the two study areas. In addition, my existing knowledge about the area and personal links have facilitated carrying out participant observation and obtaining the secondary data required (e.g. census data). The reasons and justifications for selecting the two case study areas within the eastern part of the Nile Delta (Table 3.1) are discussed next.

3.2.4 Two case study areas in the eastern Nile Delta region

Having reviewed the rationale and reasons for selecting the eastern part of the Nile Delta of Egypt to investigate land-use change in the rural-urban fringe in a semi-arid country in the developing world, this section presents justifications and reasons for selecting the two case study areas within the eastern part of the Nile Delta. The Nile Delta of Egypt covers the area from Cairo in the south to the shore line of the Mediterranean Sea in the north between the cities of Damietta in the east and Rosetta in the west (Figure 3.3a). It is divided into three main parts; the western, the middle, and the eastern Nile Delta. The eastern part of the Delta forms the most important agricultural region in Egypt (Aboelghar and Tateishi, 2002). Considering the differences between the old fertile agricultural land close to the Nile River and the recently reclaimed land adjacent to the desert area, and in line with the aim and objectives of this thesis (Chapter 1), it was decided to select two contrasting case study areas within this region (Figure 3.3b): the Alzaqazig area in the south and the Almansourah area in the north. In this context, it is important to explain the rationale for the selection of these two case study areas.

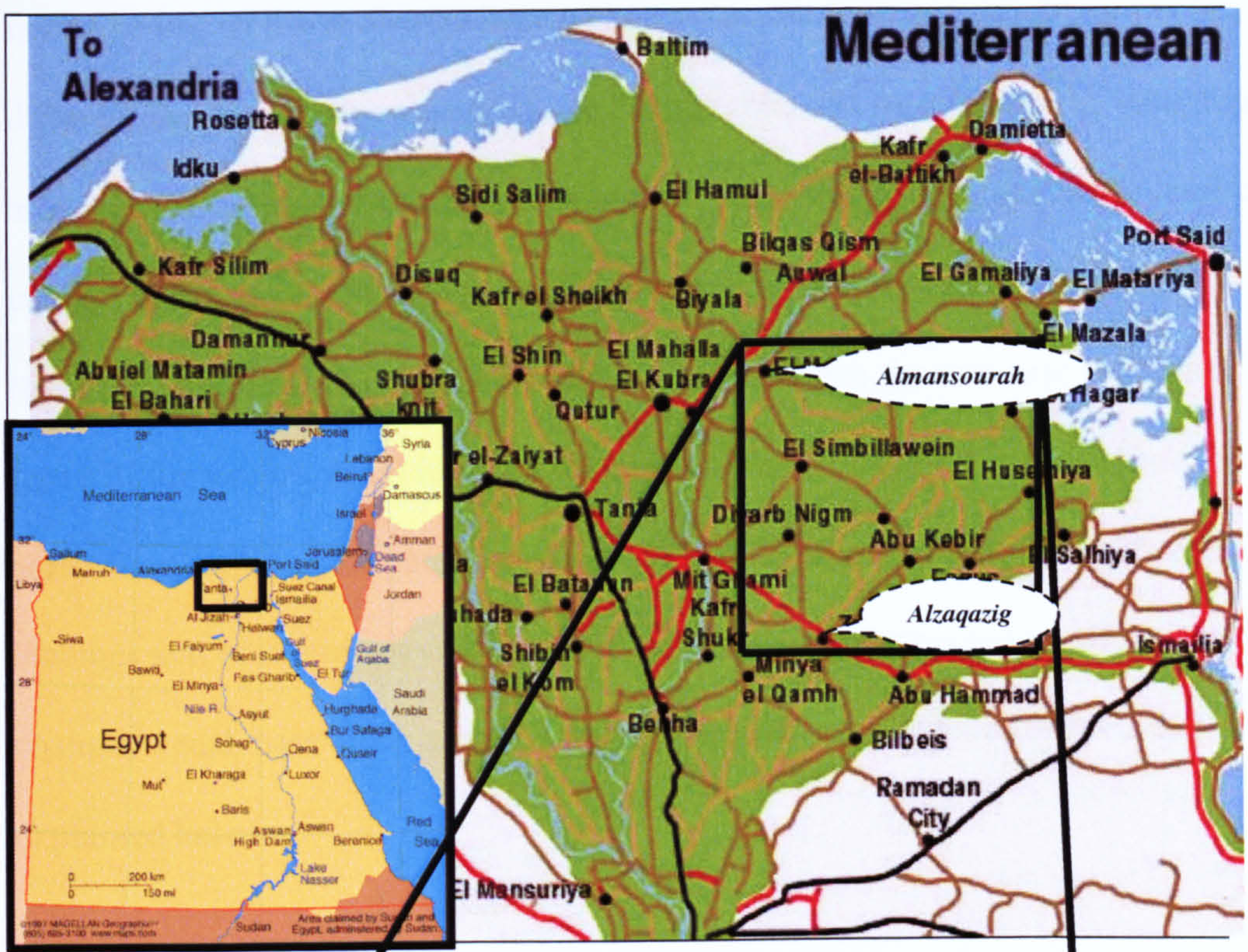


Figure 3.3A: Location of the case study region in the Nile Delta
(Source: http://www.map-of-egypt.org, 2007)

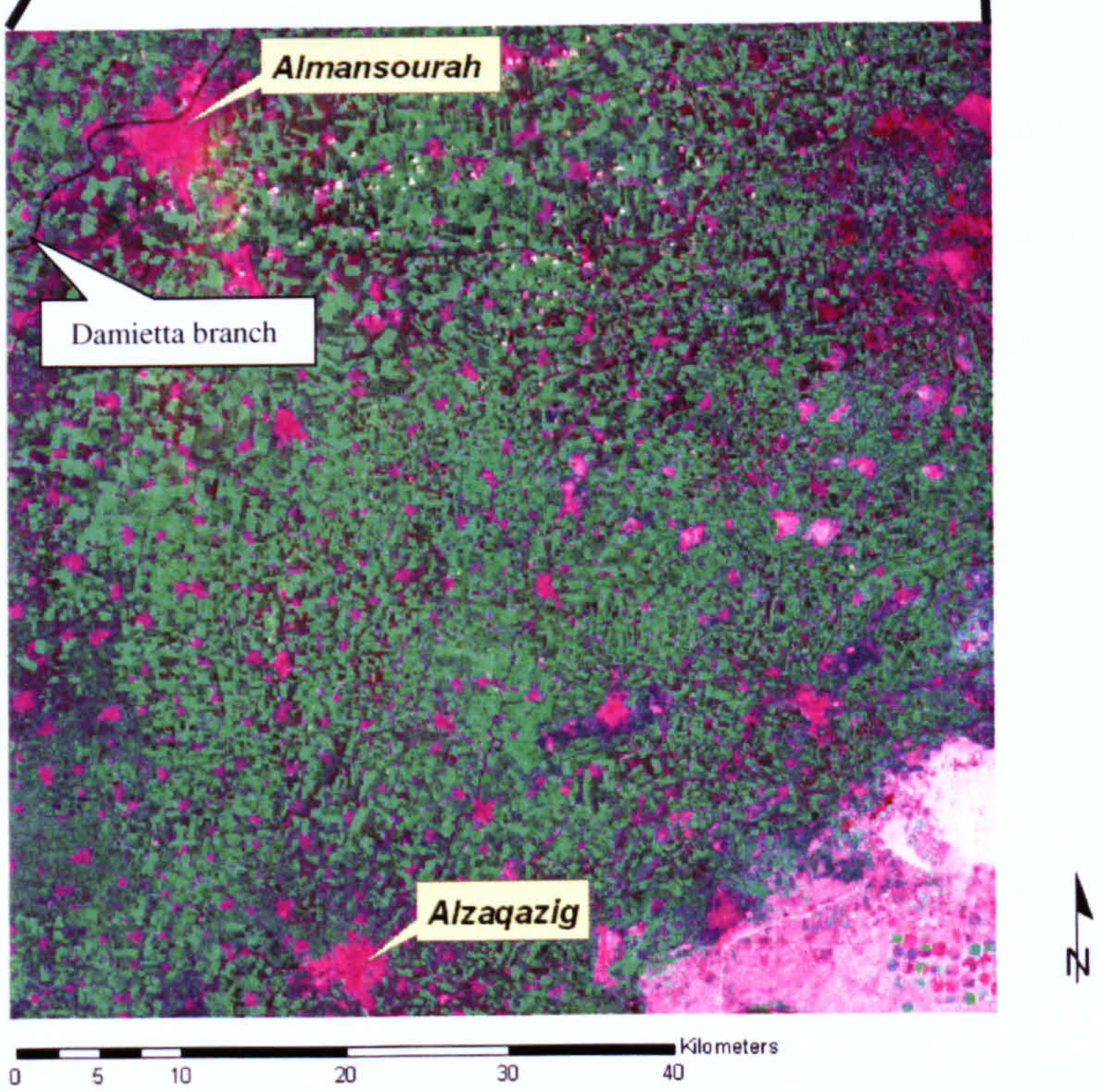


Figure 3.3b: Location of the two study areas in the research region in the eastern part of the Nile Delta (Source: Remote sensing images)

Investigating land-use change in two contrasting areas will highlight more clearly the different drivers which cause land-use change than can be achieved by studying one area alone. Comparative studies are more effective methods in analyzing land-use change as the more general versus the site specific drivers can be identified. It is, therefore, crucial to emphasize the differences between the two case study areas in terms of the geographical location (distance to the Nile River), educational and agricultural utilities, irrigation methods adopted, vulnerability to desertification, incomes and economic development. These factors are expected to affect land-use change in each case study area but their influences vary because of their differences as explained below.

The Alzaqazig study area (Plate 3.1) is the capital of El-Sharkia province in the eastern part of the Nile Delta with a population of 286,722 inhabitants in 2006 (Brinkhoff, 2006). It was established as a transportation and market centre in the 1820s when cotton cultivation was spreading in the Nile Delta. Much of the economy today in Alzaqazig is linked with local agriculture and the production of cotton, corn, rice, wheat and Egyptian clover (see also Chapter 4). One of the most important features of the Alzaqazig study area is the adjacent location to the desert. Much of the recently reclaimed land in the Nile Delta is located around the Alzaqazig study area and is associated with problems of soil salinity and land degradation (DRI, 1994; Kotb *et al.*, 2000; Gouda, pers. comm., 2005).

Plate 3.1: fields of wheat in the Alzaqazig study area.

In contrast, the Almansourah study area (Plate 3.2), which is the capital of El-Dakahlia province, is located on the eastern bank of the Damietta branch of the Nile River about 55 kilometres North West of the Alzaqazig study area (Figures 3.3a and 3.3b). The population of Almansourah was 425,824 in 2006 (Brinkhoff, 2006). It is a highly productive agricultural area and ideal for intensive cropping. The Almansourah study area is both an agricultural market and industrial centre. Manufactures include ginned cotton, cotton seed oil, and textiles. In addition, it has a respected university including 19 faculties, 2549 staff, 1990 demonstrators and teacher assistants, a total number of 121,590 undergraduate students and 6390 postgraduate students registered in the academic year 2005/2006 and occupies a site of 120 ha in extent (Almansourah university website, 2007). The existence of such an educational institute in

Almansourah and lack of one at the Alzaqazig study may lead to differences in land-use change in the two areas.

Plate 3.2: Fields of Egyptian clover (Berssem) in the Almansoura study area.

3.3 Selection of the time scale

As explained earlier, this study investigates land-use change in the eastern part of the Nile Delta during the period 1984-2003. Issues related to the spatial and temporal scales have always been mentioned as a priority for land-use and cover change investigation and modelling. Section 3.2.1 has identified and justified the use of comparing two case study areas (the spatial scale). In this section, a discussion and justification for comparing three dates (the temporal scale) for this study will be presented.

Research on modelling land-use and cover change has distinguished between static and dynamic groups of land-use change models based on their temporal characteristics (e.g.

Turner II *et al.,* 1995; Veldkamp and Lambin, 2001; Lambin and Geist, 2006). For example, using regression models in land-use change investigations to explain the spatial distribution of land-use changes as a function of a number of hypothesized driving forces can be seen as a static model of land-use and cover change (Nelson and Hellerstein, 1997; Overmars and Verburg, 2005). On the other hand, dynamic models have given specific attention to the temporal dynamics of land-use changes and have been used for predictions of future land-use change or when trajectories of land-use change were studied (Veldkamp *et al.,* 2001; Verburg and Veldkamp, 2005).

Lambin and Geist (2006) showed that different temporal scales of land-use and cover change studies have been addressed by different projects analysing changes in land-use and cover (Figure 3.4). For example, the Land-Use and Cover Change Millennium

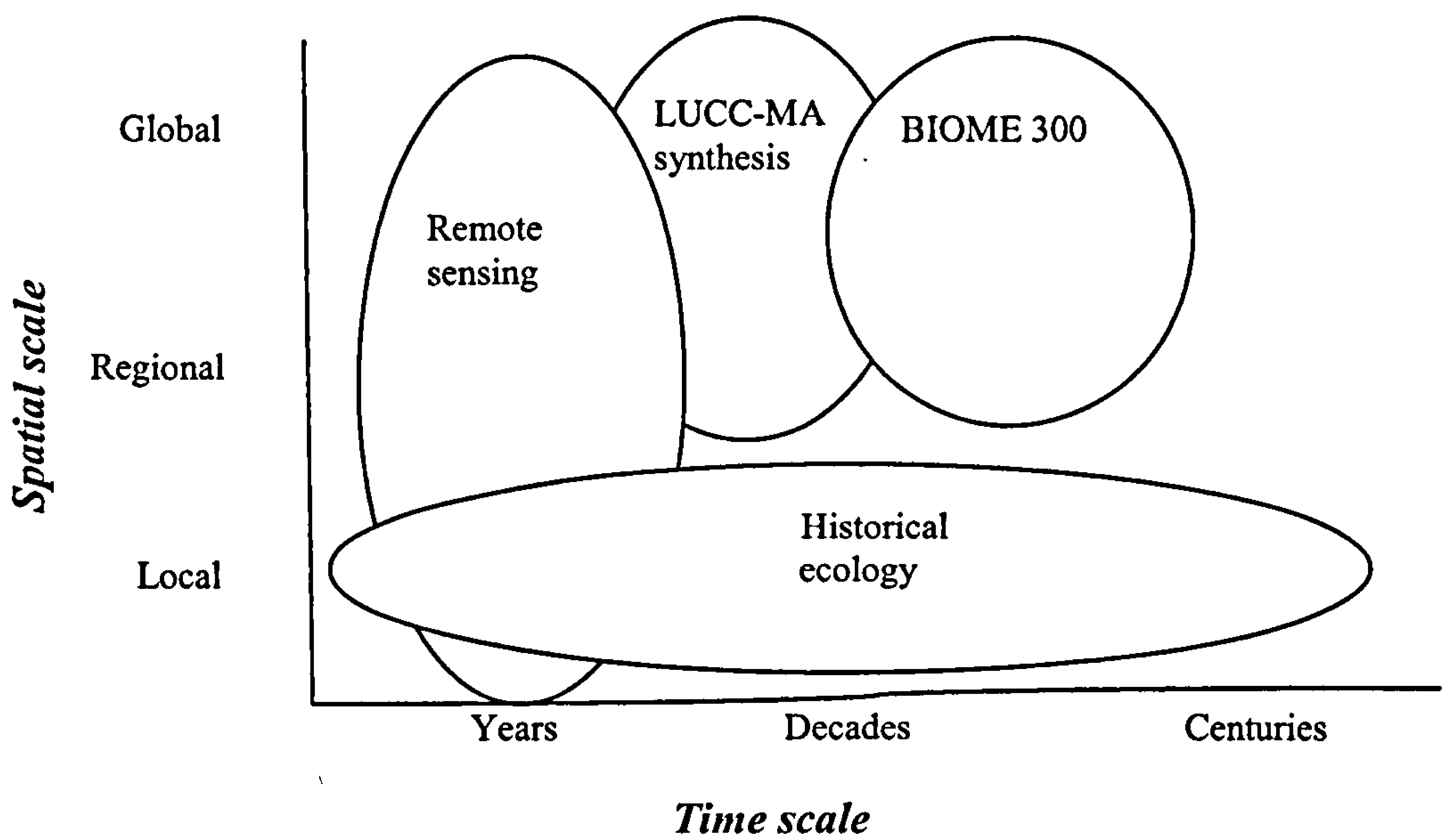


Figure 3.4: Spatial and temporal scales addressed by different land-use/cover change studies (Source: adopted from Lambin and Geist, 2006)

Assessment (LUCC-MA) conducted a detailed global synthesis of areas of land-use and cover change to map regions of the world experiencing rapid and major change in forest cover, agricultural land, degraded land, and urban areas over the recent decades. Furthermore, the BIOME 300 project uniquely addressed both large spatial scales and long temporal scales in describing agricultural land-use change.

In the present study, it was decided to investigate land-use change in the last two decades for the following reasons. First, investigating land-use change for only a short time (one to five years for example) will not achieve the main aim of this study as this period is too short to explain and interpret the changes in land-use that occurred in both study areas. Second, if the time scale exceeds 50 or 60 years, for example, this length of time will obscure the understanding of possible current driving forces that affect land-use change because global forces including World War II and the 1970s oil crisis could dominate what was happening at the farm and local level. As a result, it was necessary to select a temporal scale for this study which was situated between the short and long period. Therefore, the period 1984-2003 (last two decades) has been chosen as a time scale for this study.

3.4 Research Methods used in the case study areas

Having reviewed the overall approach adopted for this study and identified the two case study areas and the rationale for their choice, this section identifies and justifies the research methods used to collect and analyse data and to determine land-use and cover change in the two study areas in the eastern Nile Delta River of Egypt from 1983 to 2003. As mentioned in Section 3.2.2, one of the advantages of using the case study approach in such a study is the ability to utilise different types of data and information resources (cross-checking). Therefore, the present study will use five different sources of data in order to meet the objectives of the research. These methods are: remote sensing data, questionnaires, interviews with farmers and local experts, participant observation and census data. An explanation of each method is presented next.

3.4.1 Remote sensing data

As outlined in Chapter 1, one of the main aims of this thesis is to determine the key factors that drive land-use change. A thorough analysis of land-cover change at particular times is required to obtain insight into the most important factors that need to be considered. Land-cover change detection of the studied area's surface features is extremely important for understanding the relationships and interactions between human activities and natural phenomena in order to encourage better decision making (Lu *et al.,* 2004).

In recent decades, remote sensing data have been the primary resources used for most land-use and cover change detection and have been extensively employed for the purpose of identifying differences in the state of an area at different scales by observing differences at different times (Milne and O'Neil 1990; Lunetta *et al.,* 2002; Skidmore, 2002; Yang and Lo, 2002; Fraser *et al.,* 2005; Le Hegarat-Mascle *et al.,* 2005). In addition, today land-cover is usually mapped from remotely sensed imagery recorded by sensors mounted on satellites. These images have some advantages compared to alternative data sources such as aerial photography (Gibson, 2000; Robinson, 2004): they are cheap and cover large areas as well as having a high temporal frequency (Comber *et al.,* 2004).

Satellite images are composed of discrete picture elements, or pixels. Pixel sizes vary for different satellite sensors (Gibson, 2000). Early (1972) Landsat 1-5 Multi Spectral Scanner (MSS) images have a pixel size of 57m by 79m. Later (1982) Landsat multi-spectral Thematic Mapper (TM) images have a multi spectral pixel size of 30 m by 30 m (as used in this study).

In a traditional classification (further explanation about classification algorithms will follow later in this section) of an image each pixel is assigned to a certain class (e.g. crop, urban, water surface, and desert). Every pixel in an image contains spectral information averaged over the area covered by the picture element. Because a pixel grid is arbitrarily overlain on a landscape, not every pixel belongs to one distinct class. If a pixel comprises more than one class, for example rice, cotton and fallow, the spectral information from these classes is recorded as a mixture of all three. Such a pixel is called a boundary or mixed pixel. The number of boundary pixels in any image classification is dependent on the resolution of the sensor and the complexity of the landscape (El-Kady and Mack, 1994; Gibson and Power, 2000). In the case of agricultural crops, average field size, variability of the crop planting calendar and image acquisition date influence the level of detail and accuracy possible. Small fields and a dynamic crop calendar (as is found in the present study) combine to increase the number of boundary pixels in an image. A high percentage of boundary pixels in an image classification limits both the number of discrete land-use classes that can be identified and the overall accuracy of the classification.

Gibson (2000) suggested that remote sensing techniques can play an important role in the study of land-use and vegetation. He further emphasised that remote sensing data can be used in many applications of land-use change and vegetation such as:

(1) landscape change detection studies; (2) updating topographic, vegetation and land-use maps; (3) discrimination of different crop and vegetation types; (4) measurement of crop area; (5) soil type and discrimination; (6) determination of crop vigour or stress.

Many researchers have emphasised the importance of mapping land-cover classes and monitoring their changes over time, and have developed a variety of change detection techniques (Singh, 1989; Coppin and Bauer, 1996; Gupta and Prakash, 1998; Lu *et al.*, 2004). Remote sensing data have been declared by many authors to be one of the best techniques for investigating human-environment interaction, especially land-use and cover changes and have therefore been combined with socio-economic surveys and census data as well as other biophysical information gathering techniques, to bring about a better understanding of land-use and cover dynamics and the factors that drive them (Liu, 2001; Veldkamp and Lambin, 2001; Parker *et al.*, 2003; Campbell *et al.*, 2005; Guler *et al.*, 2007).

Lu *et al.* (2004), for example, suggested three main steps required for land-cover change detection: image pre-processing, selection of suitable techniques to implement change detection analyses, and accuracy assessment. In addition, they argued that change detection research should provide the following information: (1) area of change and change rate, (2) spatial distribution of change types, (3) change directions of land-cover types, and (4) accuracy assessment of change detection results. The application of these mentioned procedures will be considered in land-cover analyses in the present study. De Wit (2003) further emphasised the importance of using remote sensing data in the detection of land-cover change. However, he recognized that the application of remote sensing change detection techniques also has difficulties. One of these difficulties is that different land-cover types often have similar spectral properties, or that external factors such as clouds or soil moisture severely influence satellite images and affect result interpretation (Li and Yeh, 2004).

The limitations of automated change detection techniques as identified by De Wit (2003) have led to using other methods in order to obtain accurate change detection results. Many land-cover changes can be recognised easily by visual interpretation of satellite images. This is especially true in many countries that already have land-cover mapping projects where visual interpretation of satellite images plays an important role.

Few studies, however, have used remote sensing data to investigate land cover and land-use changes in arid and semi-arid areas. One exception is work by Lambin and Ehrlich (1997) which used a remote sensing-based technique for land-cover-change analysis in the African continent between 1982 and 1991. Their study results showed that continuous, unidirectional change processes (decrease or gain in vegetation cover) affected less than 4 percent of sub-Saharan Africa regions during the study period. Another study carried out by Palmer and Rooyen (1998) used Landsat TM data in order to explore the impacts of land management policies on vegetation structure in two study areas in the southern Kalahari Desert, South Africa from 1989 to 1994.

Several studies in the 1970s and 1980s used remote sensing data to determine areas of cultivated land-use change in different parts of Egypt. Most of these studies, however, reported problems arising from the use of Landsat MSS images resulting from the images spatial resolution available at the time. For example, in a study carried out in 1983 in Egypt trying to determine the area of irrigated agriculture using remote sensing and satellite data, the Remote Sensing Centre of the Academy of Scientific Research determined that the area of irrigated agriculture in Egypt was 2.46 M ha during the 1976 winter season using digital processing of Landsat Multi-Spectral Scanner data. However, the study concluded that Landsat MSS image's spatial resolution was not satisfactory for crop differentiation in Egypt because of the small field sizes involved (Hady *et al.*, 1983).

In 1986, a study carried out by the Egyptian Survey Authority in cooperation with the Netherlands using Landsat TM images acquired in February and July 1985 of the Fayoum area in Egypt set out to determine the total area of cultivated land, waterlogged and saline areas and urban area growth. The results from this study showed that in the Fayoum area, satellite remote sensing probably cannot help in making a detailed crop map because of the small field sizes and fragmented land-use (Wolters *et al.*, 1991). The authors confirmed that in irrigated areas of the world with small average field sizes accurate classification is impossible if the land-use is complex, with many different crops in different stages of growth next to each other.

A third study carried out in 1991 by the Drainage Research Institute in Cairo and the Winand Staring Centre in Wageningen (The Netherlands) aiming to compare data obtained from the image classification (August 4, 1984 TM of the middle part of the Eastern Nile Delta) and cropping pattern data from the Ministry of Agriculture (MOA) statistics. Three crops were classified (cotton, rice and maize) and the results showed a strong correlation existed between both data sets for the study area as a whole. However, at a more detailed scale there was only a weak correlation for cotton and rice. In addition, maize appeared to be overestimated by the MOA in the south and underestimated in the north part of the Eastern Nile Delta (Gawad *et al.*, 1991). With better technology and image analysis today, these problems have still not been totally resolved especially in the case of small fields.

In the context of land-cover class differentiation, many studies have paid significant attention to the different techniques used to distinguish between land-cover classes (see Table 3.2 which shows different methods that addressed this issue). Two main techniques were used in the present study in order to distinguish between different land-cover classes and detect land-cover changes through time. These methods are: *classification algorithm* and *Normalized Difference Vegetation Index* (NDVI).

	Study 1	***Study 2***
Author and date	***(Flores and Martinez, 2000)***	***(Bradley and Mustard, 2005)***
Aim of the study	Estimating crop acreage in small areas	To show that the response to environmental condition (rainfall) can be used to map a land cover type which not captured by any previous land cover mapping methods
Area	The basin of the Duero River	Semi-arid Great Basin
Country	Spain	US
Research method	An Empirical Best Linear Unbiased Predictor (EBLUP) estimator (ground survey and remote sensing)	- Field observation for cheat grass monoculture, native shrub/grass salt flat (non-vegetated) sites - A series of 10 LandSat TM and ETM between 1988 and 2001 - NDVI dataset, AVHRR time series
Results	-The EBLUP estimator is the most efficient of the four estimators. The worst estimator is the "Direct Expansion estimator" -The differences between the crops are explained by the fact that the spectral signatures of corn and sugar beet crops are more specific than the spectral signature of sunflower, which is usually confused with ploughed land ready for sowing.	- Land Sat time series cheat grass showed a high amplified response to rainfall compared to the other land cover types following the wet years of 1988, 1995, and 1998. - The same results in the AVHRR and NDVI.

Table 3.2: Summary of different methods for land-cover change analysis
"continued"

	Study 3	Study 4
Author and date	*(Wood et al., 2004)*	*(Panigrahy and Sharma, 1997)*
Aim of the study	- Identifying changes in land use/cover over time, and discovering the key drivers of the changes - Implications of the results for agricultural resource policy	- Obtaining crop rotation information
Area	The department of Velingara in Senegal 543.000 ha	Bardhaman district (eastern India) 7000.55 Km^2
Country	Senegal	India
Research method	-Field visits to the ground sites. - Data collection at each site (full vegetation inventory, soil profiles, assessment of natural resource condition) - Interviews (for socio-economic data) - A time series of satellite imagery (LandSat MSS+ETM)	- Indian remote sensing (IRS) data (multidate data) LISS1 - 20 ground control points (common in the map and the image) - Principal Component (PC) transformation - Band 3 and 4 (red and NIR) - Maximum likelihood classifier - Field visits (ground truth) GT
Results	The study showed by land cover classification for the time series images: - Expansion of agriculture (the amount of land that has been brought into the agriculture system between 1973 (82.855 ha) and 1999 (188.719) is an increase of 127.8% - The bush/fallow class is the young second growth.	- The accuracies of most of the rotation classes were between 90 and 97% (multitemporal PCs) - For the other classes like water, permanent vegetation was more than 97% - classification of band 3 and 4 was 89-95% accuracy for crop rotation classes and more than 95% for the other land cover classes.
	Study 5	**Study 6**
Author and date	*(Ramankutty and Foley 1999)*	*(Boyd et al., 2002)*
Aim of the study	Estimating historical crop cover change in North America from 1850 to 1992	To evaluate and explore the accuracy of three methods for estimating coniferous forest cover (vegetation indices, regression analysis and neural networks)
Area	North American continent	Western Cascade Mountains of Oregon, North western USA 2589 km^2

Table 3.2: Summary of different methods for land cover change analysis *"continued"*

Country	The continent of North America	USA
Research method	This study used the following set of data: - DIScover data (remotely sensed) combined with crop inventory data for 1992 to create a crop cover map for 1992 - The ratio of crop cover in the past to the crop cover in 1992 is derived for each political unit then converted to a spatial map	- a closed canopy conifer forest cover map from unsupervised classification of LandSat MSS - For each method then, the data were used to explore the strength of relationship between forest cover and a range of vegetation indices for instance or to derive a regression equation that describe the relationship between forest cover and the remotely sensed response observed by the AVHRR sensor - three type of neural network were investigated: MLP, RBF and GRNN
Results	- The study showed the rapid clearing of original forest/woodland in the USA from 1850 to 1992 (about 1.68 million Km^2 of Savannas/grasslands/steppe s and 1.40 million Km^2 of all original forest/woodlands have been cleared since 1850	- ten vegetation indices were found to be the most strongly related to forest cover out of 225 - NDVI was weakly related to forest cover - the regression model's ability to estimate forest cover were found to be significantly correlated with the ground data - MLP (multi-layer perceptorn) was found the most accurate estimates of forest cover

Table 3.2: Summary of different methods for land-cover change analysis

(Source: Author)

One of the most important techniques used in analysing remote sensing images is the classification algorithm. Gibson and Power (2000: 72) defined classification as "*the process by which pixels which have similar spectral characteristics and which are consequently assumed to belong to the same class are identified and assigned a unique colour*". There are two main types of land-cover classification: *supervised classification* and *unsupervised classification*. *Supervised classification* requires prior knowledge from the image analyst of the number of land-cover classes that are found in the area under investigation as well as information obtained from maps or from actual fieldwork where different land-cover classes are identified and their geographical positions are noted (Gibson and Power, 2000; Richards and Jia, 2006). In supervised classification, it is important to divide the image into a sample of training areas or training fields for each land-cover class. These training areas are used to provide the classification programme with typical examples of each type of land-cover to be used in the classification.

The disadvantages of supervised classification are two-fold. First, the "set-up" time of supervised classification is much longer than unsupervised classification because the training fields have to be identified, outlined and assessed before supervised classification can proceed. Second, training areas or fields in supervised classification are selected based on their cover types and not necessarily their spectral differences. Therefore, poorly chosen training areas or fields will yield a poor classification (Verbyla, 1995; Gibson and Power, 2000).

Unsupervised classification is a technique that groups the pixels into clusters depending on their digital numbers in the remotely sensed image (Civco *et al.*, 2002; Andersson, 2006). This process does not require any previous knowledge or input from the user nor are training areas of fields required. However, as Gibson and Power (2000) suggested, an unsupervised classification programme, such as ERDAS IMAGINE 8.7 or ISODATA clustering, may require the user to specify a number of parameters such as a maximum number of classes, a maximum number of iterations and a threshold value. One of the main advantages of using unsupervised classification is that the user does not need to have a prior knowledge of the study area required to be classified, although some information from the ground or from other independent published sources are required for successful classification. In the present study, unsupervised classification will be conducted in the two case study areas in order to distinguish between the main land-cover classes such as water surface, intensive agricultural land, urban settlements, roads, and desert land (see Chapter 4 for more description). In addition, a change detection technique was applied in order to determine land-cover changes through time (1984 and 2003) in the two case study areas of this study.

The Landsat TM data used in this study was obtained from the NPA group path-row (176-039) for the dates August 1984, November 1992, and August 2003. Although the satellite images show most of the Nile River Delta, the eastern part, where the research region is located, was the main area covered in the data. The first step in dealing with the raw satellite images data was to convert them into IMG files as they were originally in TIF format. Using ERDAS IMAGINE 8.7 as a powerful tool for analysing satellite images allowed to convert the 7 bands LandSat TM data for the whole scene into image files. The spatial resolution of 30 meter of the scene images allowed consideration of the details that reflect the main land-cover features such as water surfaces, intensive irrigated agricultural land (cropland), urban settlements, and desert land.

The *Normalized Difference Vegetation Index* (NDVI) is one of the most widely vegetation indices methods used to distinguish between different land-cover types (Defries and Townshend, 1999; Lyon *et al.*, 1998; Stefanov *et al.*, 2001; Stow and Chen, 2002; Bradley and Mustard, 2005). The NDVI, like most other vegetative indices, is calculated as a ratio between measured reflectivity in the red and near-infrared bands of the electromagnetic spectrum. These two spectral bands are chosen in the calculation because they are most affected by the absorption of chlorophyll in leafy green vegetation and by the density of green vegetation on the surface. Also, in red and near-infrared bands, the contrast between vegetation and soil is at a maximum.

The NDVI transformation is computed as the ratio of the measured intensities in the red (R) and near-infrared (NIR) spectral bands using the following equation:

$$NDVI = (NIR - R) / (NIR + R)$$

The NDVI equation produces values for each pixel in the image between -1 and +1. Vegetated areas will typically have values greater than zero and negative values indicate non-vegetated surface features such as water, barren land, sand, or urban settlements. In the present study, the NDVI will be used in association with unsupervised classification in order to, first, differentiate between different land-cover classes and second, calculate the rate of changes in land-cover through time (1984, 1992 and 2003) (see Chapter 4 for more detail).

Table 3.2 above shows that using remote sensing data to identify land-cover classes is one of the most widely adopted techniques. However, it is also apparent from the table that most studies have used a second or third source of data in order to verify the accuracy of the results. Therefore, as mentioned earlier in this chapter, other sources of primary information will be used for cross-checking. The use of questionnaires is discussed in the next section.

3.4.2 Questionnaire data

There is general agreement amongst authors and researchers in social science studies and human geography projects that questionnaires are the most widely used data collection method, not only for collecting the data required, but also for collecting the data in a relatively accurate way (Brace, 2004; Flowerdew and Martin, 2005; Robson, 2007). Questionnaires, therefore, are an important means of obtaining primary data which is required to enable the researcher to answer the research questions and achieve the objectives of the study. In the context of human geography and social science investigations, the use of questionnaires is fundamental as a tool when primary data are required about people, their behaviour, attitudes and opinions and their awareness of specific issues.

In the early stages of questionnaire design, Flowerdew and Martin (2005) suggested that two main issues must be addressed: *reliability* and *validity*. *Reliability* suggests the capability of the results to be replicated and *validity* means that the questionnaire is able to measure what it was intended to do. Based on these two crucial issues, they further emphasised that the content of the questionnaire must reveal the research question or hypotheses under investigation.

Oppenheim (1992) argued that it is possible to distinguish between two main types of questionnaire surveys: *descriptive* and *analytical*. *Descriptive* questionnaires are commonly conducted in large scale surveys, such as those carried out by national institutions which are mainly concerned with counting numbers of people in particular categories and with particular characteristics. *Analytical* questionnaires meanwhile, are more concerned with explanations and causality especially in exploring the more difficult "why" questions and are, therefore, more frequently adopted by academic researchers. He further identified four types of variables that should be considered in an analytical questionnaire:

1. *Experimental* or *explanatory variables*. They are also referred to as *independent* variables and include the causes or the drivers that may be possible predictors of the main effects that are being studied. Examples of independent variables in the

context of the present study are: farmers' educational level, women's role in agricultural production, and farm product transportation costs.

2. *Dependent variables.* These variables represent the results produced by the impact of the independent variables. A change in land-use is a dependent variable which could be influenced by a combination of several independent variables.
3. *Controlled variables.* These are the variables that are held constant when exploring the relationships between the dependent variable and a number of particular independent variables.
4. *Uncontrolled variables.* These include all variables other than those mentioned in the experimental and controlled variables and can influence the results.

Flowerdew and Martin (2005) suggested that, the extent to which these four types of variables can be identified depends on the researcher's knowledge of the topic. They further emphasised that in the development of research hypotheses a simple causal model is rarely under consideration. More often, a complex set of interrelated independent variables may influence the dependent variable and a multi-causal model must be considered.

Advantages and disadvantages of using questionnaires in social science studies and related fields as suggested by Robson (2007) can be summarised as follows:

Advantages:

1. Questionnaires are very cost effective when compared to other data collection tools such as interviews. This is especially true for studies involving large sample sizes

and large geographic areas. Written questionnaires become even more cost effective as the number of research questions increases.

2. Questionnaires are easy to analyse. Data entry and tabulation for nearly all types of questionnaire surveys can be easily done with many computer software packages.
3. Questionnaires are familiar to most people. Nearly everyone has had some experience completing questionnaires and they generally do not make people apprehensive.
4. They do not require personal interaction skills on the part of researcher.

Disadvantages:

1. It can be very difficult to obtain acceptably high response rates.
2. Questionnaires do not facilitate discussion of topics in depth, as long and complex questionnaires reduce response rates.
3. It is very difficult to check the veracity of answers, or to assess the seriousness with which participants have approached the task.
4. Careful planning, design and attention to details are required at all phases of the research.

Questions included in a questionnaire can be asked and data recorded in different ways. Oppenheim (1992) for example, suggested that most questions included in a questionnaire are either *open* or *closed.* Closed questions are usually designed in a way that the respondents have the choice of alternative answers. Questions of this type may offer simple alternatives such as *yes* and *no*, or a choice of a category of age groups in which the respondents are asked to tick or underline their chosen answers. Open questions, however, do not offer any kind of choice, and the respondents are asked to give their answers using their own words in full. Broadly speaking, most questionnaires used in different research fields include a mixture of both open and closed questions. The advantages and disadvantages of open and closed questions, as suggested by Oppenheim (1992), are shown in Table 3.3.

Type of questions	***Advantages***	***Disadvantages***
Open questions	Freedom and spontaneity of the answers Opportunity to probe Useful for testing hypotheses about ideas or awareness	Time-consuming In interviews: costly of interviewer time Coding: very costly and slow to process, and may be unreliable Demand more effort from respondents
Closed questions	Require little time No extended writing Low cost Easy to process Make group comparison easy Useful for testing specific hypotheses Less interviewer training	Loss of spontaneous responses Bias in answer categories Sometimes too crude May irritate respondents

Table 3.3: Advantages and disadvantages of open and closed questions
(Source: Oppenheim, 1992)

Flowerdew and Martin (2005), meanwhile, argued that questionnaire data can be broadly divided into three main types of data: the first type *classifies* people, their circumstances and their environment. Examples of these data are: age of respondent, income, household size and variables related to the respondent's location. The second type of data is related to the *behaviour* of people: for instance, how often do they use fertilisers in their farms, or where do they get rid of their farm manure. The third type of data is related to people's *attitudes, opinions and beliefs*: this type of data is the most difficult category of data to be collected because of nature of attitude questions which are vulnerable to biased responses depending on how they are asked, in addition to the respondent's tendency to please the interviewer.

In the context of the present study, the questionnaire (see Appendix I) was designed to include different types of questions related to both farmers' characteristics and behaviour in terms of their agricultural practices as well as land-use change (causes, consequences and responses) on the other. The aim of the questionnaire was to collect primary data and information from the two case study areas and to complement remote sensing data. The framework was provided by the candidate indicators that represent the components of the DPSIR framework (see Section 3.5 for detailed information). The questionnaire was divided into five sections covering different areas of investigation.

Section one:

This section provided basic information about the farmer and his/her personal characteristics. It included information about age, ownership of the farm, farm size, educational level, additional education and time spent living in the village. The aim of asking these questions in this section was to collect the required data needed to investigate the relationship between land-use change as a dependent variable and farmer's personal and cultural characteristics as the independent variables.

Section two:

Section two of the questionnaire was concerned with some of the farm practices. In this section, farmers were asked questions about crop types, livestock, agricultural rotation practices, land-use change patterns and reasons for change if applicable, irrigation systems and fertiliser and pesticide use. The purpose of asking these questions was to collect the required qualitative and quantitative data needed for the statistical analysis.

Section three:

The third section of the questionnaire was focused on the possible economic drivers which could affect land-use change in the two case study areas. Questions included in this section covered availability of agricultural and private source subsidies, transportation availability and cost and expenditure on reducing soil degradation.

Section four:

This section was concerned with any information related to increase or decrease in farm land. Two main questions were asked in this context. The first question was about any decrease in the farm size due to desertification process, and the second question was concerned about any increase in the farm land size due to possible land reclamation projects in the area.

Section five:

Section five involved social and cultural drivers which could affect land-use change. Questions included in this section were focused on the role of the family in agricultural production, rural women's contribution in agricultural production, social and family planning programmes and a farmer's general satisfaction level of his[1] farm production income.

[1] In the author's experience, only men own farms in Egypt.

Having reviewed the design and structure of the questionnaire used to collect primary data, the next step in the development of the data collection is to define the *sample* of the study.

Collecting data using questionnaire surveys is usually conducted by sampling from a population rather than contacting all members of the population. Flowerdrew and Martin (2005) emphasised that two main questions must be addressed and answered clearly by the researcher before dealing with sampling methods. These questions are:

(1) what are the appropriate *units* of study?

(2) What is the *target population*?

The unit of study could be individuals, groups, or organizations. In the present study, as the prime interest is individual's decision making, farmers form the unit of the study. The target population of any study is defined by a number of different elements such as a geographical boundary, a temporal boundary and a boundary defined by population characteristics. In terms of the resent study, the target population is defined by different criteria as explained below.

Having decided in Section 3.2.4 on the location of the two case study areas, the next step was to draw a sample of villages from each case study area. The main criteria for choosing farm samples from the two study areas were:

1- As the focus of this research is to look at land-use changes in the rural-urban fringe, the villages under investigation should be located at the interface of the rural-urban fringe (a distance not exceeding 10 km from the city centre).

2- To ensure a wide geographical allocation and spatial consideration, the village samples should be located in a north-south and east-west orientation in each case study area.

3- Villages and farms under investigation should be representative. That means the sample in the rural-urban areas should signify the geographical distribution of different types of land-use and crops in the whole area.

4- A variety of farms of different size were included as the size of farm is an important factor in determining farm management behaviour.

As a result, four rural villages in each case study area were selected (Table 3.4). With assistance of personnel from the Extension Department, Ministry of Agriculture, 120 farmers from the Alzaqazig study area and 120 farmers from the Almansoura study area were selected. Information from 25% of the farmers in the study areas was found to be unreliable and therefore excluded from the analysis. As a result, interviews for 100 farmers in the Alzaqazig area and 80 farmers in the Almansourah area were judged valid for inclusion. There was probably a greater number of questionnaires that were unreliable in the Almansourah study area because the farmers were more educated and more suspicious that the author was collecting data for tax purposes. The farmers were interviewed between the 10th of November 2005 and 15th January 2006.

The Alzaqazig study area	**The Almansourah study area**
Kafer Mousa omran (north)	Attawellah (north)
Bordeen (south)	Minyat Sandoub (south)
Ghazalah (east)	Sallant (east)
An-nakhass (west)	Oesh Elhagar (west)

Table 3.4: The four villages studied in each case study area

3.4.3 Interviews

Interviews are another important source of primary information used to complement both questionnaires and remote sensing data. Authors in the social sciences and other research contexts have acknowledged the usefulness of interviews as a data gathering technique in their investigations (Oppenheim, 1992; Singleton *et al.*, 1993; Silverman, 2004). Briggs (1986:1) goes so far as to emphasise that *"estimates suggest that 90% of all social science investigations use interview data in one way or another"*. Interviews are able to provide empirical data and relevant information about the subject under investigation by asking people to talk about their lives, experiences and, more importantly, to understand the perceptions of the respondents. In this respect, many researchers have considered interviews as special forms of conversation (Holstein and Gubrium, 1995; Silverman, 2004). Although these conservations may vary from highly structured, standardized, quantitatively oriented survey interviews, to semi-formal guided conversations, to free-flowing informational exchanges, all interviews are interactional.

Oppenheim (1992) argued that, when using interviews, as a data collection technique, the most important determinant both of response rate and of the quality of the responses is the subject's motivation. For this reason, it was very important for the interviewer to explain how the particular respondent came to be selected for the sample and why it was important that he should take part in this particular investigation. For this thesis, interviews were used to complement information gathered through questionnaires, remote sensing data, census data and participant observation. Interviewees were selected on the basis of the following methodological steps:

1. Interviewees needed to be based in both case study areas.

2. Four different locations were selected in each of the case study areas (8 in total) based on differing farm sizes and other farm characteristics. In each of these locations it was hoped to interview 2 respondents (n=16 in total). All targeted respondents had been part of the questionnaire survey, which meant that the researcher already had some basic information concerning their farms and land-use change processes.
3. Interview respondents were selected, first, on the basis of differing farm sizes (i.e. representing differing land-use options); second, on the basis of specific responses given by the respondents in the questionnaire (e.g. specific pathways linked to land-use change); third, through help and advice given by the extension department personnel in both case study areas.
4. Out of the 16 targeted respondents, 6 farmers agreed to be interviewed and were keen to participate in the interviews. Three farmers were located in each case study area, and each of these three respondents represented either small, medium or large farms, thereby providing information on the whole cross-section of farms in the area (in relation to farm size).
5. With the help of the extension services, and in compliance with the University of Plymouth ethics code, respondents were guaranteed anonymity and that their responses would only be used for academic purposes.

At the outset, the interviewer explained the advantages to the interviewee of taking part, namely that the information would be part of a large study on land-use change in the Nile Delta which might contribute to agricultural research in the future. As a result, the response rate was excellent and all the interviewees were keen to participate.

Some factors included in the analysis (e.g. soil salinisation, type of crops and desertification) required additional information from experts in the two study areas. As a result, four interviews with crop production, soil science and rural development experts were conducted. In addition, information obtained from six in-depth interviews with farmers from the two case study areas (three from Alzaqazig and three from Almansourah) will be discussed to provide additional information on land-use change.

3.4.4 Participant observation

Participant observation formed another method used to cross-check and triangulate data obtained through questionnaires and interviews, and to further validate remote sensing data. Participant observation is one the methods used widely in social science and human geography studies. Robson (2007:85) argued that "*as the term suggests, participant observation is defined by the role taken by the observer. He/she, to some greater or lesser extent, actually participates in the situation being observed*". This method is usually used to describe what goes on, how things happen, who or what is involved and moreover, it is an appropriate methodology for studying processes, relationships among people and events (Jorgensen, 1989; Flowerdew and Martin, 2005). One of the main advantages of using participant observation is that the researcher can obtain a deeper and more detailed insight about the activities that the individuals of a society perform and the ways in which they think. It also allows the researcher to gain a good overview of how and why a society functions (De Walt and De Walt, 2002; Robson, 2007).

Data and information gained by applying participant observation are typically written or taped as accounts of what has been observed. De Walt and De Walt (2002) outlined the importance of using participant observation as a data collection tool in social science studies. They stressed that participant observation provides several advantages to research. First, it enhances the quality of data obtained during fieldwork. Second, it helps in the interpretation of other data gathered. Third, participant observation encourages in some cases the development of new research questions and hypotheses which may be raised from the case study under observation.

Problems encountered through participant observation are also discussed by many authors and researchers in different social science and human geography fields. Robson (2007), for example, suggested that participant observation is a demanding and time-consuming way of gathering data. It can be a problem also finding opportunities to record or make notice of what has been observed while it is fresh in mind. The researcher may encounter difficulties in being accepted by people or target population in the observed area. The data obtained by participant observation can be very valuable both in terms of quantity and quality, and hence require careful analysis and interpretation. As explained in Section 3.2.3, my background, existing knowledge about the study area and personal links were important and facilitated carrying out participant observation. There were different ways in which participant observation was conducted in the study areas. Repeated visits to farms and observing farmers in day-to-day activities were the most important approaches during the field work. A close relationship developed with some farmers and the author was invited to have meals with farmers' families and talk about their agricultural production, land-use and problems they encounter. All these approaches were important and facilitated conducting participant observation and obtaining the secondary data required such as census data, an issue which is presented next.

3.4.5 Census data

Census data were an important secondary source of information and were used in this study to complement other forms of data collection. For example, population growth is one of the possible driving forces affecting land-use change (Section 2.4.4). Therefore, the use of census data is important to track population growth in the two study areas during the last two decades. The main source of data used to investigate urbanisation processes will be remote sensing images analysis. In addition, census data will play a crucial role as further evidence of the extension of urban areas towards agricultural land. In terms of responses of land-use change, census data of rice production (area development, prices and yields) as part of changes in agricultural policy in Egypt in 1986/1987 will also be used to investigate land-use change in the Nile Delta during the period 1984-2003. Organising and categorising all data and information obtained from the five sources of data mentioned above was done using the DPSIR method which will be explained further in Section 3.5.

3.5 Application of the DPSIR method

In Chapters 1 and 2, it was argued that the DPSIR model is an analytical framework that recognises the complexity of the interactions between human activities and environmental problems and provides a comprehensive means of analysing them (Elliot, 2002; La Jeunesse *et al.*, 2003; Odermatt, 2004; Scheren *et al.*, 2004; Holman *et al.*, 2005; Agyemang *et al.*, 2007). The DPSIR model has been adopted as the key conceptual framework for analysis of land-use change in the two case study areas in this thesis (see Section 1.3). In addition, as one aim of this study is to apply and critique the DPSIR framework used in an arid and semi-arid environment, the methods used for data collection with the DPSIR framework will be discussed.

The DPSIR model will also be used to explore the inter-relationships between the five main components of this framework (Figure 3.5). It is important in this context also to mention that analysing and testing the significance of the relationships between the independent variables (driving forces and responses) and land-use change as the dependent variable, will be conducted using SPSS (Statistical Package for the Social Sciences) software.

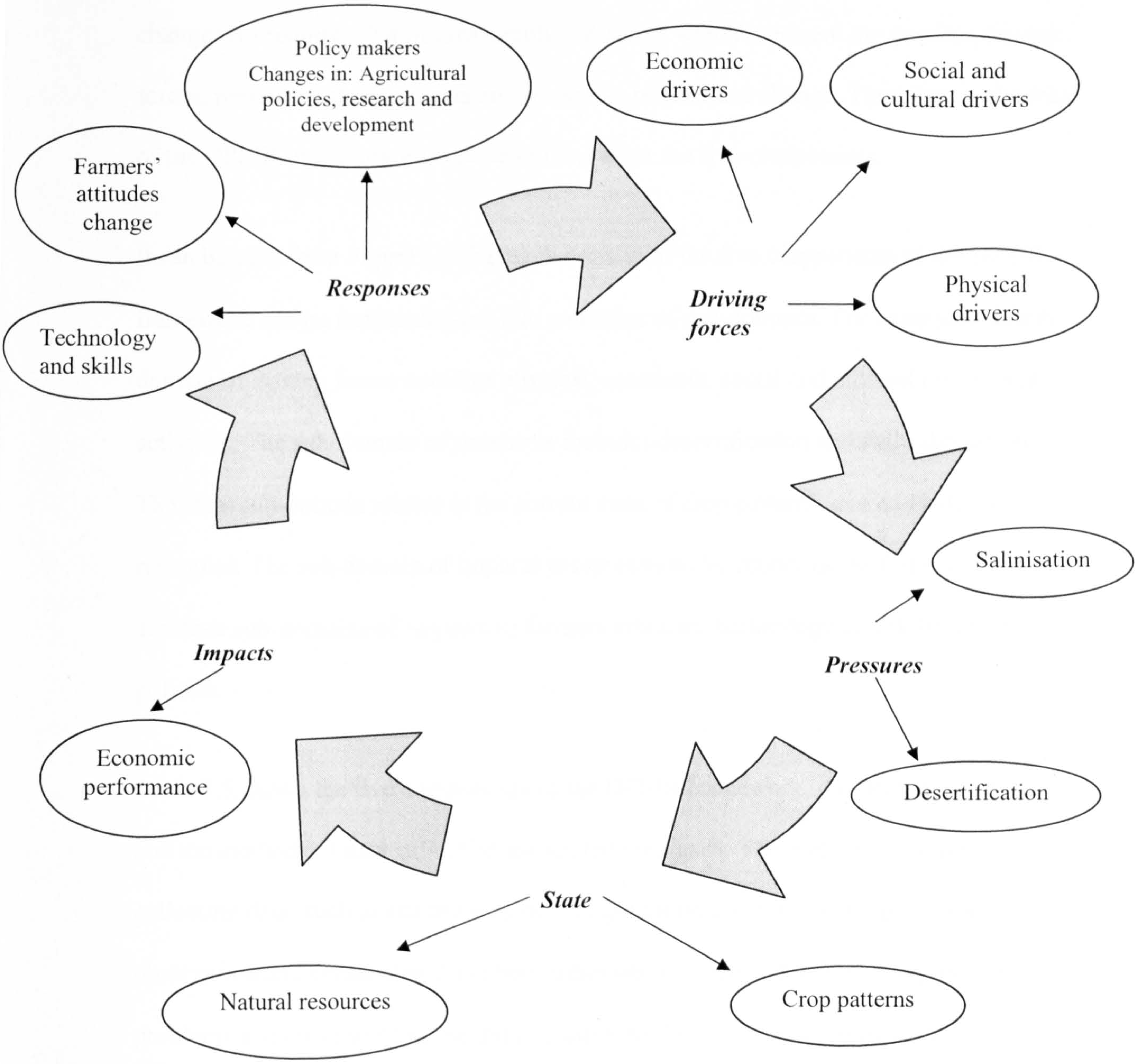


Figure 3.5: The DPSIR framework developed for this study of land-use change

(Source: Author, after Costantino *et al.*, 2003; Kristensen, 2004)

Despite the potential capabilities and the extensive application of the DPSIR framework in different fields, especially in the assessment of environmental problems and land-use change investigation and its potential to contribute to the formulation of related policies, its adoption and application are still at the foundation stage in many developing countries such as Egypt. Applying the DPSIR as a method for analysis of land-use change will require a list of measurable indicators which represent the possible driving forces, pressures, state, impacts and responses of land-use change. Therefore, a checklist of the DPSIR indicators was created to represent the five components.

It can be seen from Figure 3.5 that each domain of the five components of the DPSIR framework can be further divided into a number of sub-domains. For example, the sub-domain of *driving forces* contains physical, economic, social and cultural drivers and activities. The sub-domain of *pressures* includes desertification and soil salinisation. The *state* sub-domain relates to the current state of crop patterns area and natural resources. The sub-domain of impacts is represented by economic performance. There are three sub-domains of *responses;* farmers attitudes, technology and skills and public policies.

Table 3.5 shows the five components of the DPSIR framework, the related indicators and the methods of data collection associated with each. The methods used for collecting data, such as remote sensing, the questionnaire, interviews, participant observation and census data have been described in Section 3.4. However, there were problems acquiring some of the data because the datasets did not exist or there were problems accessing them. Where it was possible, triangulation and cross-checking were used to check the veracity and validity of the data. In developing countries, the availability and accessibility of data may impose some limitations on land-use change analysis. In some cases, the data are simply not available. In others, the data exist in government files but cannot be accessed for bureaucratic reasons.

The checklist of the DPSIR indicators as shown in Table 3.5 is integrated throughout the entire approach. Checklists can be valuable tools because they are comprehensive and include all the fundamental social, economic and environmental factors. However, the indicators included need to be selective. The criteria for selecting the individual indicators are therefore fundamental to the success of the approach. In this thesis, 29 indicators were selected and their criteria will be detailed below (Table 3.5).
The driving forces affecting land-use change are crucially important within the DPSIR framework as they affect pressures, state, impacts and responses. The indicators of the driving forces were determined on the basis of the hypotheses of this study which have been stated in Section 2.6. Indicators of the driving forces will include physical, economic as well as social and cultural drivers (see Table 3.5). Pressures indicators, meanwhile, will represent two procedures by which land-use and agricultural production are affected. These processes are: soil salinisation and desertification. Impacts indicator in this study is focused on economic performance. Expenditure on reducing land degradation is considered to measure the impact of land-use change in this study. Responses indicators will include the reactions taken by individuals (farmers) and the government. Individuals' responses included the percentages of farmers receiving new skills and training, while governmental responses considered agricultural policy change, social policies, agricultural advice and settlement of reclaimed areas.

Domain	Sub-domain	Indicator	Source of data
Driving forces	Physical drivers	1. The need for irrigation water. 2. Use of fertilisers. 3. Use of agricultural pesticides.	*1-Interviews & participant observation* *2-Questionnaire* *3-Questionnaire*
	Economic drivers	4. Subsidies availability (policy). 5. Private Banks loan availability. 6. Access to transport services. 7. Cost of transportation. 8. Current prices for crops.	*4-Questionnaire& interviews* *5- Questionnaire& interviews* *6- Questionnaire& interviews* *7- Questionnaire& interviews* *8-Not Available at farm level*
	Social and cultural drivers	9. Population growth. 10. Farmers' educational levels. 11. Rural women contribution in agriculture.	*9-Remote sensing &census data* *10- Questionnaire* *11- Questionnaire& participant observation*
Pressures	Desertification	12. Area affected by desertification	*12- Remote sensing& questionnaire*
	Salinisation	13. Soil salinisation.	*13-Interviews & participant observation*
State	Natural resources	14. Soil quality. 15. Area affected by salinisation. 16. Land affected by desertification.	*14-Not Available at farm level* *15-Interviews & participant observation* *16- Remote sensing& questionnaire*
	Crop patterns	17. Type of crop planted in rural areas. 18. Area of crop planted in rural area. 19. Number of crops planted in one year.	*17-Questionnaire, interviews& participant observation* *18-Remote sensing* *19- Questionnaire & interviews*
Impacts	Economic performance	20. Expenditure on reducing degradation.	*20- Questionnaire*
Responses	Farmer's attitudes	21. agricultural education (% of GDP) 22. access to information	*21-Not Available at farm level* *22-Questionnaire& interviews*
	Technology and skills	23. % farmers receiving new skills and training. 24. Expenditure on research and development as % of GDP. 25. Irrigation system adopted.	*23-Questionnaire* *24-Not Available* *25-Questionnaire & participant observation*
	Public policies	26. Agricultural policy change. 27. Social policies. 28. Agricultural extension. 29. Settlement of new areas.	*26- Interviews & participant observation& census data* *27- Questionnaire* *28- Questionnaire* *29- Interviews & participant observation*

Table 3.5: A Checklist of the DPSIR indicators and method used for data collection

3.6 Conclusions

This chapter has discussed and explained the research methodology used in this thesis. The introduction reviewed the various research methods adopted by different land-use change studies and justified the methods used in the present study. In the second section, the importance of the spatial scale issue and justification for the selection of the interface between farm and local scale for this study was addressed. This section also identified the case study approach as a key methodological step of the research addressed in this thesis. The rationale for selecting the Nile Delta of Egypt as a research region and justification for choosing the two case study areas in the eastern part of the Nile Delta were presented. The third section of the chapter provided reasons for the selection of the past two decades (1984-2003) as a temporal scale for the investigation. Five research methods used to collect and analyse data and to determine land-use and cover change in the two study areas in the eastern Nile Delta River of Egypt from 1983 to 2003 have been outlined: remote sensing images, questionnaire data, interviews, participant observation and census data. The last section of this chapter presented the application of the DPSIR framework in this study and limitations and difficulties encountered during the measurement of the framework's indicators.

Having discussed and explained the methods used in this study, a description of the physical, agricultural, economic and human characteristics of Egypt in general and the research region in particular and changes in agricultural policies as a response at the regional level is of crucial importance and presented next in Chapter 4.

Chapter 4: Egypt and the two study areas: geography, population issues and agriculture

4.1 Introduction

Chapter 3 has outlined and discussed the research methodology adopted in this thesis and explained the rationale for selecting the research region in Egypt and the two study areas in the Nile Delta. This introductory chapter to the results and analysis section of this thesis describes the physical, human and agricultural background of Egypt in general terms and presents detailed results about the research region and the study areas (Alzaqazig and Almansourah). This information will act as a general platform for the understanding of land-use change processes analysed in Chapters 6-10. A description of the physical, human and agricultural characteristics of Egypt and the Nile Delta is presented in the next section.

4.2 Physical background

Egypt covers an area of slightly over 1 M km^2 (about four times the size of the UK) and is located in the north-eastern corner of Africa with an extension into Asia between latitudes 22° and 32° N and longitudes 25° and 34° E (Figure 4.1). It is bordered in the north by the Mediterranean Sea, in the east by the Gaza Strip, Israel and the Red Sea, in the south by Sudan and in the west by the Libyan Arab Jamahiriya. Egypt's north-south extent is about 1080 km, and its maximum east-west extent about 1100 km. The Egyptian land area consists of a massive desert plateau interrupted by the Nile Valley and Nile Delta which occupy only about 3.4 percent of the total country area (FAO, 2005a). The geological history of Egypt has produced four major geographical regions of the country (Said, 1990):

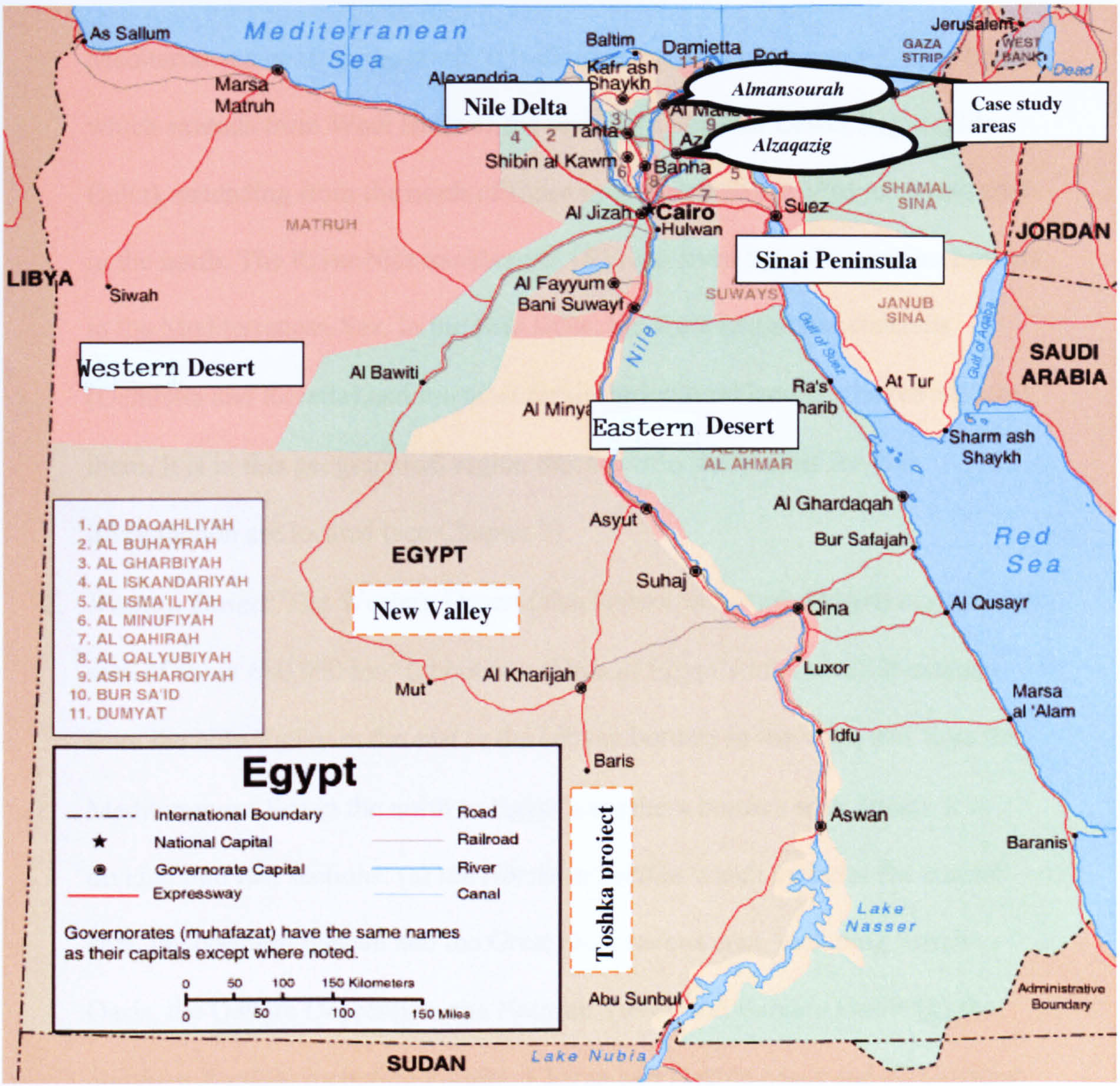


Figure 4.1: A general map of Egypt showing the locations of the four main parts
(Source: http://www.map-of-egypt.org, 2007)

1. *Nile Valley and Delta*: the Nile valley and Delta forms the most extensive oasis on earth. This part of Egypt extends in the south from north of Wadi Halfa, a Sudanese town that was completely rebuilt on high ground when its original site was submerged in the reservoir created by the Aswan High Dam, up to the Mediterranean coast in the north. It is divided into two main areas: Upper Egypt, which extends from Wadi Halfa to the south of Cairo and Lower Egypt (Nile Delta), extending from the north of Cairo in the south to the Mediterranean cost in the north. The River Nile travels over 1532 km from Egypt's southern borders to the Mediterranean Sea. In the Nile Delta, there are two major channels (Damietta and Rosetta) and the most fertile agricultural land is situated adjacent them. It is in this geographical region that the case study areas for this investigation are located (see Chapter 3)
2. *Western Desert*: The Western Desert (also known as Libyan Desert) occupies an area of about 680,000 km^2 (about two thirds of Egypt's total area). It extends from the Nile Valley in the east to the Libyan borders in the west, and from the Mediterranean Sea in the north to Egypt's southern borders with Sudan. It is divided into two sections: (a) *the Northern Section* which includes the coastal area, the northern plateau and the Great Depressions area, including Siwah Oasis, the Qattara Depression, the Natroun Valley and Baharia Oasis. (b) *the Southern Section:* including Farafra, Kharga and Dakhla oases and Al-Owainat to the extreme south.
3. *Eastern Desert*: This is also known as the Arabian Desert. Its area is about 225,000 km^2 and characterised by the eastern mountain that range along the Red Sea with peaks that rise up to about 1000 metres above sea level. The Eastern Desert is generally isolated from the rest of the country. There is no oasis

cultivation in the region because of the difficulty in sustaining any form of agriculture. Except for a few villages on the Red Sea coast, there are no permanent settlements. The importance of the Eastern Desert lies in its natural resources, especially oil.

4. *Sinai Peninsula:* this triangular area, whose base rests in the north and its head in the south, covers about 6100 km^2 (6 percent of Egypt's total area). Similar to the desert, the Sinai Peninsula contains mountains in its southern sector which are a geological extension of the Red Sea Hills. It includes Mount Catherine, the highest mountain in Egypt which rises about 2642 m above sea level.

Egypt's climate can be described with reference to temperature (Table 4.1), precipitation (Table 4.2) and humidity (Table 4.3). The climate is categorised as semi-arid in the north (Nile Delta and Cairo), arid in the middle part and extremely arid in the south (Aswan). This aridity has implications for land-use and land-use change processes, and is a key reason for situating this study within Egypt (see Chapter 3).

Temperature Mean Daily Value (°C)		***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***	***Monthly Average***
Alexandria	***High***	18.4	19.2	20.4	24.4	26.7	28.8	29.9	30.1	29.6	27.5	23.9	20.1	***24.92***
	Low	8.7	9	10.8	13.5	16.3	20.0	22.5	22.9	21.0	17.4	13.8	10.2	***15.51***
Cairo	***High***	18.8	20.5	23.4	28.4	32.0	34.2	34.4	33.9	32.6	29.6	24.7	20.2	***27.73***
	Low	9	9.8	1.7	14.7	17.5	20.4	21.7	21.9	20.4	17.9	13.8	10.3	***15.67***
Aswan	***High***	21.0	24.9	29.5	35.0	38.7	41.0	41.0	40.3	38.5	38.2	28.3	24.2	***33.38***
	Low	8.1	10.3	13.8	19.1	23.0	25.2	26.3	26.0	23.6	20.3	14.7	10.8	***18.43***

Table 4.1: Mean daily temperature at three locations in Egypt

(Source: http://www.climate-charts.com, 2007)

Precipitation Mean Monthly Value (mm)	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Monthly Average*
Alexandria	51.0	27.0	13.0	4.0	1.0	0.0	0.0	0.0	1.0	11.0	29.0	52.0	*15.75*
Cairo	7.0	4.0	4.0	2.0	0.0	0.0	0.0	0.0	0.0	1.0	3.0	5.0	*2.17*
Aswan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*

Table 4.2: Mean monthly precipitation at three locations in Egypt

(Source: http://www.climate-charts.com, 2007)

Relative Humidity Mean Value (%)	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Monthly Average*
Alexandria	69.0	67.0	67.0	65.0	66.0	68.0	71.0	71.0	67.0	68.0	68.0	68.0	*67.92*
Cairo	59.0	54.0	53.0	47.0	46.0	49.0	58.0	61.0	60.0	60.0	61.0	61.0	*55.75*
Aswan	40.0	32.0	24.0	19.0	17.0	16.0	18.0	21.0	22.0	27.0	36.0	42.0	*26.17*

Table 4.3: Mean monthly relative humidity values at three locations in Egypt

(Source: http://www.climate-charts.com, 2007)

The Nile Delta, Egypt is one of the oldest intensely cultivated areas on earth (UNEP/GRID-Arendal, 2005). It is very heavily populated, with population densities up to 1500 inhabitants per square kilometre (Gehad, 2003). Almost all the irrigation water used in Egypt in general and the Nile Delta in particular comes from the River Nile. In the Nile Delta, the river runs through two main branches (Rosetta in the west and Damietta in the east) to the Mediterranean Sea, a distance of about 200 km (Gehad, 2003). The eastern part of the Nile Delta, where the two study areas are located, has a semi-arid climate with two main seasons; hot dry summers and cool dry winters. The average annual air temperature is 20.7° C and the total precipitation for the year is 38 mm (Aboelghar *et al.*, 2002).

Linked to these geographical characteristics, one of key issues in Egypt is population pressure and the need to develop some agricultural resources further. It is, therefore, crucial to discuss the importance of population pressure and its impact on agricultural land. This issue is the focus of next section.

4.3 Population factors

4.3.1 Population pressures

With a population of 75 million today (compared to only 11 million in 1907), Egypt has the 16th largest population in the world and the largest population in the Arab region. Egypt's population growth rate was 1.9% from 1990 to 2005, placing Egypt well above the mean (1.56% for 1990-2000) for lower middle-income countries (Awad *et al.*, 2005).

Rapid population growth in Egypt generally and in the Nile Delta in particular is straining natural resources as agricultural land is being lost to urbanisation. The pressure of an increasing population combined with the scarcity of cultivable land, leads farmers to demand more from the land than it can yield (Belal, 2006). The pressure increases all the more rapidly as the spatial growth of human settlements, especially cities, takes a direct toll on the surrounding land resources. Based on FAO data in 1996, it has been estimated that between 1973 and 1985 Egypt lost 13% of its farmland to urban expansion.

One important issue should be raised in the context of the effects of the population growth problem in Egypt generally and the Nile Delta more specifically. In addition to the encroachment onto agricultural land for housing and industrial development and as a result of growing demand for new houses, the use of topsoil to produce bricks has seriously degraded some agricultural areas. Until early in the twentieth century this was not a serious problem as annual flooding deposited more soil but this is no longer the case. Substitution of sand for mud bricks can minimise the problem, but since sand bricks must be produced commercially and mud bricks can be home produced, this would deprive poor households of income. The government recognised the problem and has made topsoil mining for bricks illegal, but enforcement is very difficult (Hanna and Osman, 1995; Afifi, pers. comm., 2005).

The high population density puts a heavy burden on Egypt's infrastructure and services, and there has been massive migration to Cairo and Alexandria, resulting in urban overcrowding. This explains why Egypt has turned to its deserts for expansion, despite the heavy costs involved and the impact on its limited water resources (UNDP, 2003). The pressure of rapid population growth on agricultural land has long been recognised in Egypt, but in earlier decades it was hoped that the development of new communities created by irrigating desert land (giant projects like Toshka in the south western desert and Assalam in Sinai Peninsula) would solve the problem (Cochrane and Massiah, 1995).

4.3.2 Urban extension into agricultural land in the two study areas

Rapid population growth has been one of the main causes of serious pressures on the valuable agricultural land in Egypt and in the Nile Delta particularly (Cochrane *et al.*, 1995; Khalifa *et al.*, 2000). Rapid population growth in the two study areas during the past 20 years is evident from the population census data (Table 4.4).

Study area	*Year*			*% increase*		
	1986	*1996*	*2006*	*1986-96*	*1996-06*	*1986-06*
Alzaqazig	**244354**	**267351**	**286722**	**8.6%**	**6.8%**	**14.8%**
Almansourah	**317508**	**369621**	**425824**	**14.1%**	**13.2%**	**25.4%**

Table 4.4: Population growth in the two study areas between 1986 and 2006
(Source: Brinkhoff, 2006)

Figures 4.2- 4.5 show the encroachment of urban settlements (houses, industrial areas, commercial buildings and potential valuable bare land for future use) into agricultural land over time (1984 and 2003). The area and percentages of the increase of the urban settlement into the agricultural land are shown in Table 4.5.

Year	*Study area (ha)*		*% change*		
	Alzaqazig	*Almansourah*	*Years*	*Alzaqazig*	*Almansourah*
1984	1365.48	1961.55	*1984-2003*	*24.4%*	*28.1%*
2003	1806.12	2729.16			

Table 4.5: Urban settlement change over 20 years (1984-2003) in the two study areas
(Source: ERDAS IMAGINE 8.7 images analysis)

These data confirm that long-term land-use change in the two case study areas is linked to population growth. The rate of change in land-use from one type to another is closely associated with the rate of growth in population numbers.

The urban extension between 1984 and 2003 in the Almansourah study area is shown in Figures 4-2 and 4-3 and for the Alzaqazig study area in Figures 4-4 and 4-5. The figures highlight the increase in urban area into agricultural land (note the increase in the area of red colour between 1984 and 2003). In the Almansourah study area (Figures 4.2 and 4.3), it is clear that the increase in urban and rural-urban areas has occurred on the fringes towards the crop fields. In the Alzaqazig study area (Figure 4.4 and 4.5) meanwhile, there has been both increase in urban and rural-urban areas that occurred in the suburbs towards the agricultural land, and further extension into new land at the border with the desert. These results confirm that pressures on agricultural land are increasing and the need to find additional areas for agricultural land expansion is important. The next section will describe the agricultural characteristics of Egypt and the Nile Delta in general and the two study areas in particular.

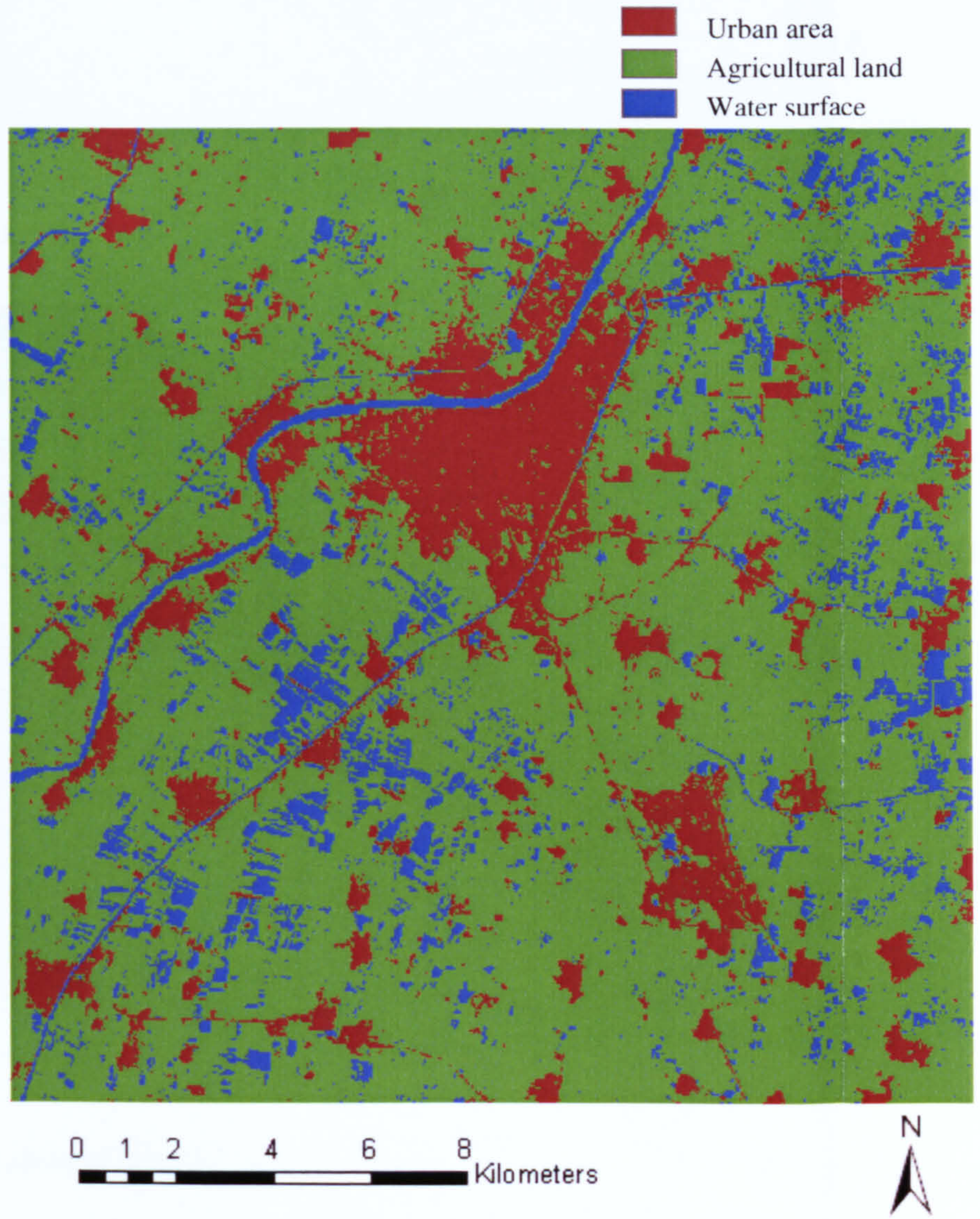


Figure 4.2: Urban area and agricultural land in the Almansourah study area, August 1984

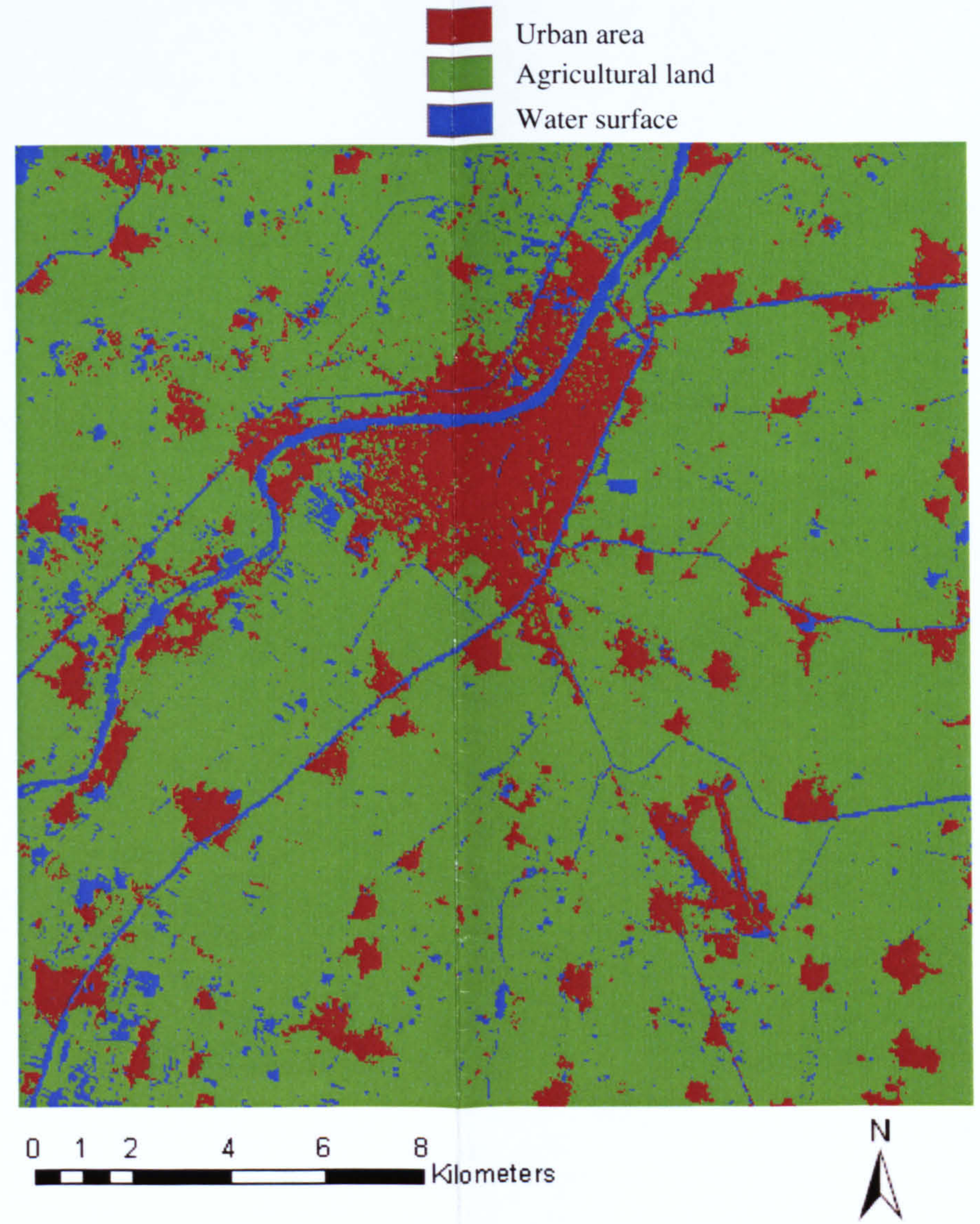


Figure 4.3: Urban area and agricultural land in the Almansourah study area, August 2003

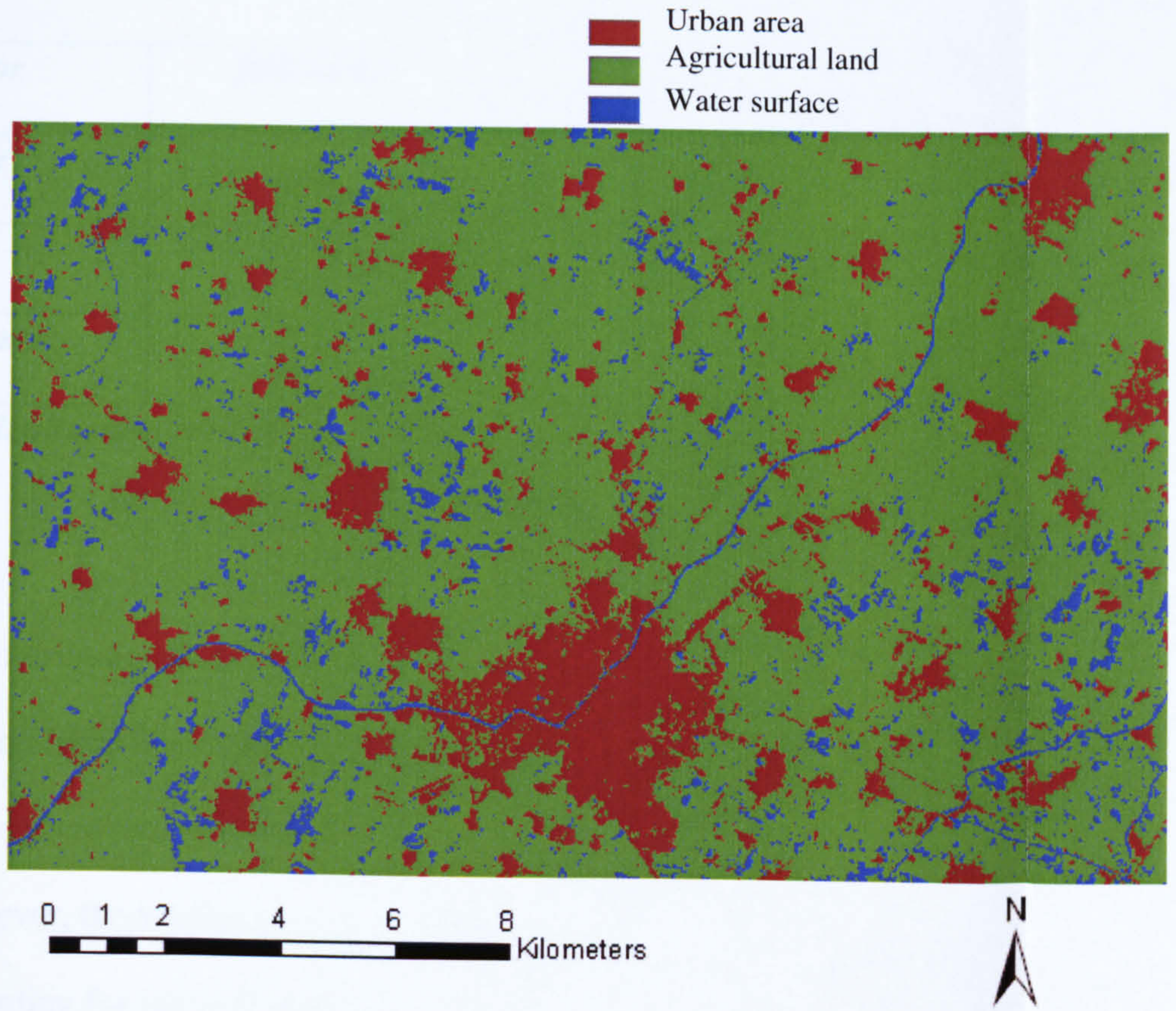


Figure 4.4: Urban area and agricultural land in the Alzaqazig study area, August 1984

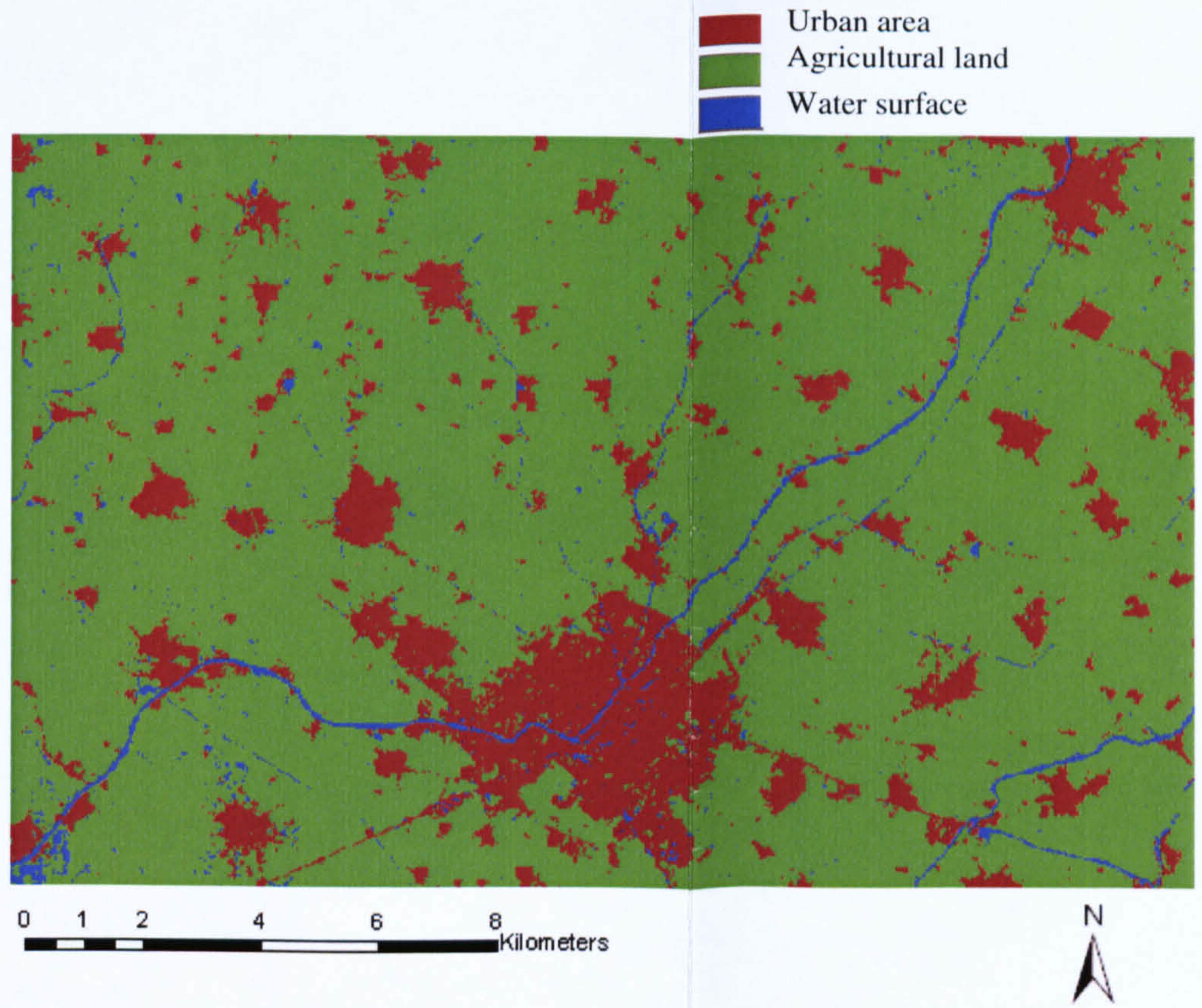


Figure 4.5: Urban area and agricultural land in the Alzaqazig study area, August 2003

4.4 Agricultural background

4.4.1 Agriculture in Egypt: patterns and processes

Agriculture is an important sector in the Egyptian economy and provides work for 29% of the national labour force and contributes 16.8% of the Gross Domestic Product (GDP) (Table 4.6; 2001/2002).

Indicator	*2000/2001*	*2001/2002*	*2002/2003*
Labour	29%	27.7%	26.9%
GDP	16.5%	16.8%	16.8%
Investments	14.4%	13%	14.1%

Table 4.6: Agricultural contribution to the national economy 2000/2001-2002/2003
(Source: Abdelelfattah, 2005)

Agriculture's contribution to the GDP in the 1995/1996 fiscal year was estimated at about $7.2 billion (nine times higher than that of tourism) (Belal, 2006). This means that the progress in agricultural production is fundamental for the development of the economy. However, the total area of agricultural land in Egypt is only approximately 3.4 M ha accounting for just 3.4% of the total surface area (Figure 4.6). A further 2% of the total area has the potential of being developed for agricultural production, bringing the total to 5.4%. About 30% of the agricultural land in Egypt is either of poor or low quality, due to salinity and water logging problems (FAO, 2005a). Crops are cultivated in winter and summer at an average intensity of 2.3 crops a year. Farms in the Nile Delta, as in Egypt generally, are very small. Nearly 50% of farms are less than 0.42 ha and 95% of landowners have farms of less than 2 ha. Cultivated land per farmer in

Egypt is approximately 0.05 ha, and so Egyptian farms rank amongst the smallest in the world (Khalifa, 1999; Kotb *et al.*, 2000).

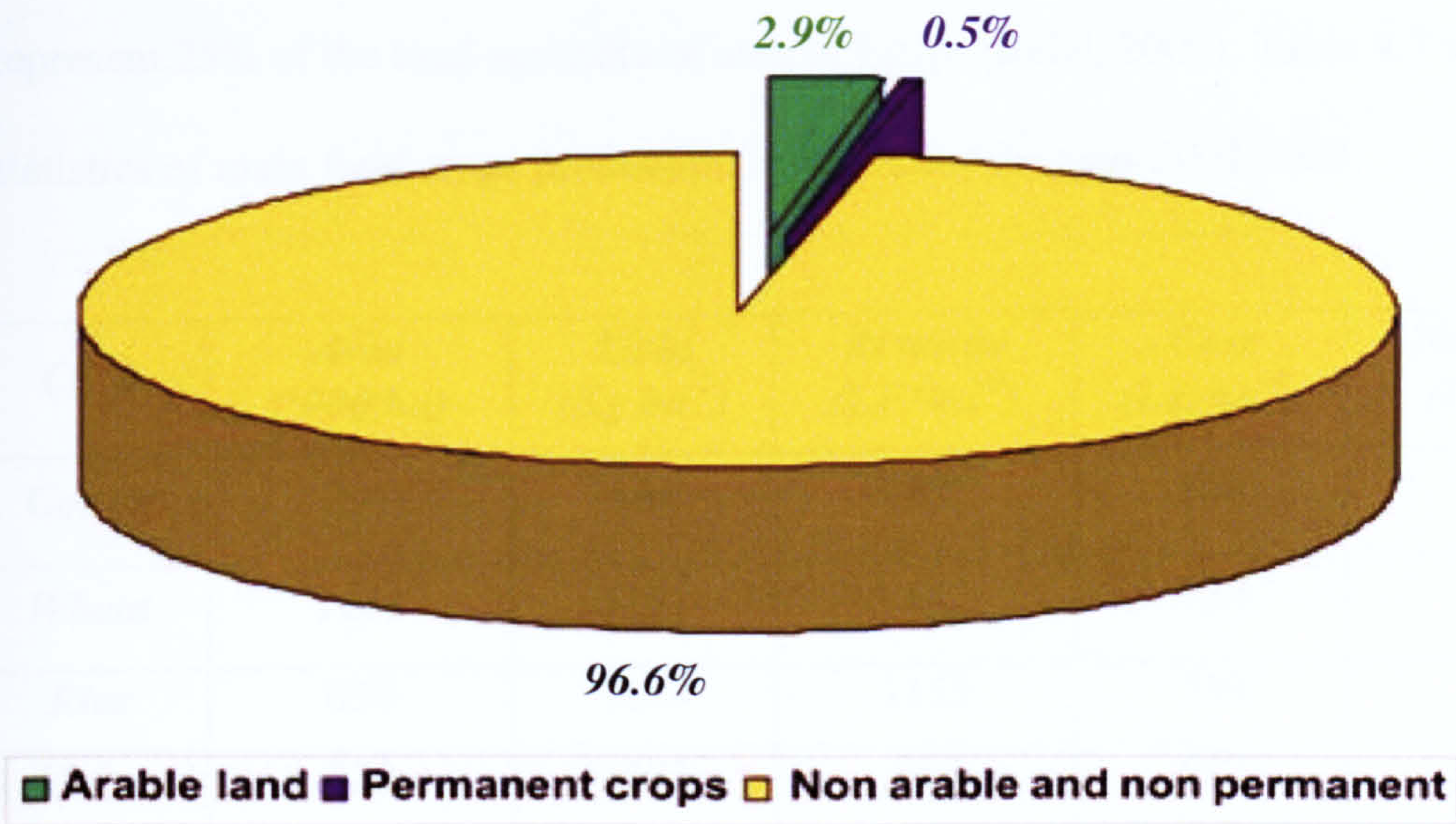


Figure 4.6: Land-use in Egypt (Source: Ministry of Agriculture and Land Reclamation, 2003).

Crops in Egypt are cultivated under irrigation with the use of organic and inorganic fertilizers. Water for irrigation in the Nile Delta generally comes from two sources: either directly from the Nile River or one of its branches (fresh water) or from drainage systems that comprise reused water of poor quality (Attia, 2004; Gouda, pers. comm., 2005). This system of reusing used drainage water is common in the northern parts of the Nile Delta where there is a shortage of fresh water and other parts of the Middle East.

The main crops planted in the Nile Delta are: cotton, wheat, rice, maize and Egyptian clover (Berseem), accounting for 80% of all crops cultivated (Belal, 2006). Wheat and Egyptian clover are the main winter crops; in summer, cotton and rice are important cash crops, while maize and sorghum are the subsistence crops. Compared with countries with similar agro-climatic conditions, levels of production are relatively high and yields have increased significantly in the last five years. There is considerable potential for growth, particularly in the approximately 1 M ha of reclaimed land, which represent 25% of the total agricultural area in Egypt (Belal, 2006). Table 4.7 shows the statistics of main field crops production in Egypt for the year 2002/2003.

Crop	*Area ('000 ha)*	*Yield (Kg ha^{-1})*	*Revenue (LE*ha^{-1})*	*Cost (LE ha^{-1})*	*Net return (LE ha^{-1})*
Cotton	297	462	1221	866	355
Wheat	1053	1147	1147	720	427
Rice	650	1659	1152	739	413
Maize	770	1373	968	622	346

Table 4.7: Field crops: areas, yields and returns, 2002/03 (Source: National Agricultural Income, 2002; Agricultural Statistics, 2003).

** Egyptian Pound.*

About 95% of local agricultural production is consumed domestically, despite the increased emphasis on cash crops for export, especially cotton and horticultural products such as fruits and green beans. Cotton is Egypt's major agricultural export and was for many years the most extensively subsidised crop. Egypt also exports crude petroleum products, mineral and chemical fertilizers, and iron and steel. Meanwhile, Egypt is one of the world's largest wheat purchasers (Siam, 2006), importing around US$1107 million in 2005 and US$888 million worth in 2006. Wheat as the major cereal crop in Egypt is fundamental to the government's food security policy. The Egyptian government has adopted a policy of reducing wheat purchases and is encouraging farmers to increase the area of wheat to achieve a greater rate of self-sufficiency. Efforts to increase food production, in particular wheat, have received top priority in the agricultural development programmes since the implementation of the first Five-year Development Plan starting in 1983.

In the context of Egypt's food security policy, its wheat policy has two main dimensions. The first dimension is concerned with food availability, where the main focus is to increase the self-sufficiency ratio of wheat production from the level of 53.3% in 2003 to full self-sufficiency (Table 4.8). The main way of encouraging wheat production is the price incentive the government pays to wheat producers through the setting of a procurement price that is higher than the import price. The second dimension is to ensure greater accessibility of low-income households to food, and in particular to bread.

	1985	*1990*	*1995*	*2000*	*2003*
Total consumption (million MT)*	6,238	10,033	12,100	12,093	12,839
Domestic production (million MT)	1,872	4,268	5,080	6,455	6,840
Self-sufficiency ratio	30.0	42.5	42.0	53.4	53.3

Table 4.8: Wheat consumption, production, and self-sufficiency ratio in Egypt between 1985 and 2003 (Source: Ministry of Supply and Home Trade, 2005)

* *Metric tonnes.*

Farmers in the Nile Delta take several factors into consideration when choosing which crops to plant (MPWWR-WC, 1996):

- Amount of land available.

- Amount of water available.

- Amount of work required to grow the crop.

- Type of soil.

- Crop previously grown on the land.

- The season.

- Household needs.

- Price of crops.

- Transportation availability.

There have been many changes in government policies towards agricultural production generally and crop production in particular. In the past, farmers were required to follow government policies for crop production (quotas, prices and crop type). Therefore, it is important to briefly consider these changes and their effects on farmers and the agricultural sector in the following section.

4.4.2 Agricultural policies

Agricultural policies have been identified both as a key driver for land-use change (Goueli and Elminiawy, 1993; Meyer and Turner II, 1994; Olesen and Bindi, 2002) and also as a response (see Section 4.5) and, therefore, warrant closer scrutiny. In the early 1960s, the Egyptian government regulated the area and production of many crops including cotton, wheat, rice, and sugar cane. In addition, the farmer was obliged to deliver all or part of his production to the government at a fixed price, which was lower than the free market price. The government handled marketing and processing. The justification of these policies was that the agricultural sector is interconnected with other sectors of the economy. The system also specified the quantity, crop variety and the quantity and type of fertilizers and pesticides to be supplied to farmers for each season. Farmers were subject to financial penalties for breaching the cropping pattern. These policies had negative effects on the performance of the agricultural sector, as there were large numbers of people transferring from the agricultural sector to other sectors (FAO, 1995; Ender and Holtzman, 2002).

Until 1976, farmers in the Nile Delta and other parts of Egypt received agricultural input loans from the Agrarian Credit Bank and agricultural cooperatives. However, Saddik (1995) argued that this system resulted in shifting the main role of agricultural cooperatives in guiding farmers and promoting agricultural production and limited it to the distribution of inputs. In addition, interference of functions and responsibilities between the Agrarian Credit Bank and agricultural cooperatives supervised by other bodies made credit services rather unorganised and unlimited. As a result, Law 117 of 1976 was issued and the Principal Bank for Development and Agricultural Credit (PBDAC) was established in order to finance agricultural activities. Therefore, agricultural credit and agricultural cooperatives were again separated. The PBDAC is authorized to provide credit services to both farmers and agricultural cooperatives (Siam and Mousa, 2003).

The PBDAC system is the only source of institutional agricultural credit available to small farmers. This institution makes short-term, medium-term and long-term loans to farmers at subsidized rates of interests. However, this system has followed a very conservative lending policy. Loans for farm equipment, for example, require more than 20 hectares security for tractors and more than 1.25 hectares for water pumps. These policies have limited the ability of small farmers and tenants to obtain credit for mechanization or other medium and long-term credit (Goueli and El Miniawy, 1993). On the other hand, village banks are highly bureaucratic and inflexible. The “Supervised Credit Approach” of PBDAC has been subject to criticism for supplying a fixed package of inputs, and this approach stripped farmers of important choices. Moreover, by obliging PBDAC to check on the use of the input it supplied, supervised credit actually raised the costs of administering loans (Saddik, 1995; Mansour and Ghanima, 1997).

During the period 1960-1976, the concept of integrated credit, research and extension services was adopted (the agricultural cooperatives were specifically authorised to provide services related to organising and directing the agricultural sector). This concept was extremely effective as it allowed the development of credit services to all farmers, especially small ones. The bank also extended its activities to include hundreds of village banks distributed among all the productive agricultural regions in such a way that the distance between any farmer and the place where s/he can obtain credit services should not exceed 5 km (Saddik, 1995). In addition, the agricultural credit policy of the PBDAC provided farmers with credit services under different forms since its inception, even though the applied credit policy was constantly changed according to prevailing political and economic circumstances.

All farmers were the beneficiaries of the credit service, whether big or small landowners or tenants. This is due to a structure characterised by the domination of small (less than 2 hectares) holdings (67% of the cultivated areas and about 95% of the farmers at the national level; Saddik, 1995).

In 1980, a significant reform of these agricultural policies was introduced as a framework for agricultural sector strategy for the 1980s. By 1987 the Ministry of Agriculture had initiated an economic reform programme concerning prices and marketing control, delivery quotas for the main crops, and reduced subsidies for inputs

(Siam *et al.*, 2002). It encouraged private sector investment in crop marketing and the supply of inputs. In 1993, the agricultural sector was completely liberalised. The main implications were:

- Governmental control of farm and output prices and crop areas was removed.
- Governmental control of the private sector with regard to imports, exports and distribution of inputs, as well as the import and export of agricultural crops, was removed.
- Subsidies on farm inputs were eliminated.
- The role of the Principal Bank for Development and Agricultural Credit was diverted to the provision of financial services.
- Governmental ownership of land was limited.
- "New land" was sold to the private sector.
- The role of the Ministry of Agriculture was restricted to agricultural research, extension, legislation and economic policies.
- The land tenancy system was modified.

These reforms, especially those involving the removal of governmental controls on areas planted, prices and marketing, had a positive impact on crop production and, as Chapters 6-9 will discuss in detail, were a key driver for land-use change in the post 1993 era. They improved the value and profitability of crop rotation, resulting in an increase of more profitable crops compared with crops of lower profitability (FAO, 2005a; Belal, 2006). Changes and reforms of agricultural policies in Egypt have led to some impacts on land-use patterns and crop areas in the two study areas as on other parts of the country. Before describing the changes and crops affected in the two study areas in Section 4.6, further details on the governmental policy changes as a response to land-use change will be given in the next section.

4.5 Changes in agricultural policies

4.5.1 Introduction

Section 4.4.2 presented a key description of the development and reforms of agricultural policies in Egypt from the early 1960s till 1993. The discussion highlighted the main changes and reforms of agricultural policies with regards to governmental subsidies and crop prices control. A summary of changes in agricultural sector as a result of Structural Adjustment Economic Reform Programme in Egypt during the period 1987-1997 is presented in Table 4.9.

Date	*Action taken*
1987	- Removal of compulsory procurement of all crops with the exception of paddy rice, cotton and sugar cane. - Procurement made optional at floor prices for wheat, maize and other crops.
1990	- Official Effective Rate (ER) was devalued from US $ 1.43/LE to US$ 0.5/LE and free market ER was decreased to US$ 0.34/LE.
1991	- Removal of compulsory procurement of paddy rice. -Optional procurement with farm price for paddy rice. -Elimination of exchange rate subsidy for imported inputs. -Partial reduction of input subsidy (about third). -Official and free market ER was unified at US$ 0.3/LE.
1992	- Cotton procurement prices were increased to 66 percent of the previous 5 year average of world price. -Elimination of all crop area controls except for minimum area requirements for cotton and maximum area of paddy rice. -More reduction of input subsidy (second third). -Start liberalizing long rental relationship (transition period from 1992-1999)
1993	- Elimination of the remaining input subsidy (the last third) with the exception of pest control subsidy. -Elimination of cotton area control (however, regional allocation of cotton varieties among districts is still under government control)

***Table 4.9: Specific Actions of Structural Adjustment Economic Reform Programme (SAERP)** "continued"*

1994	- Private sector was allowed to compete with the public sector in buying, selling and ginning seed cotton. - The old administrative marketing system was allowed to continue (until 1996 when complete liberalization took place)
1995	- Private sector was allowed to export cotton as well as buying from farmers and ginning. - A minimum floor price policy for cotton was adopted with minimum price higher than world price.
1997	- Land rental relationship is fully liberalized as of Sept. 1997 (The end of the 5 year transition period according to the new law)

Table 4.9: Specific Actions of Structural Adjustment Economic Reform Programme (SAERP) (Source: Siam *et al.*, 2002)

The main aim of this section is to evaluate to what extent changes in agricultural policies during the period 1984-2003 have affected land-use change and crop production. In this section, changes in agricultural policies in the two study areas will be investigated in the context of agricultural policies in the Nile Delta in general. This is because the implementation of agricultural policy changes in the two study areas will be identical. While Section 4.5.2 will discuss irrigation policy in Egypt in general, the discussion in Section 4.5.3 will focus on rice area, production, yield and prices as rice is the most important crop in terms of water consumption. Section 4.5.4 will discuss agricultural policies in the reclaimed areas adjacent to desert land.

Before discussing these issues, it is important to have another look at the current agricultural development strategy in Egypt at the present time. Sabaa and Sharaf (1998) have argued that the government's strategy depends on two main dimensions: horizontal development and vertical development.

Horizontal development: This dimension depends on a number of large programmes and projects designed for reclamation and cultivation of desert land. This is regarded as the only way to reduce the pressure of population density in the old land of the Delta and the Nile Valley. Moreover, these projects contribute to increasing the agricultural production and generate new job opportunities. More than 0.5 M ha were reclaimed since 1952. At present, the large project at Toshka (see Figure 4.1) aims to reclaim more than 0.2 M ha in the short-term and about 0.57 M ha in the long-term. Similarly, a land reclamation project in the Sinai Peninsula aims at reclaiming about 0.17 M ha. In addition, about 0.13 M ha will be reclaimed in the New Valley (see Figure 4.1).

Vertical development: This dimension aims at increasing agricultural production per unit area:

- Planting of high yielding and disease resistance varieties.
- Distribution of certified seeds and encouraging the private sector to produce high quality seeds.
- Adoption of the latest and up-to-date technology available used in crop production including the use of machinery.
- Improving the quality of soils and increasing its fertility.
- Using advanced irrigation methods.
- Improving and supporting the agricultural extension system.

These responses will have effects on driving forces, pressures, state and impacts of land-use change. The duration of these responses to make a difference will vary depending on the problem targeted (see Chapter 5 for more detail). The next section will discuss changes in irrigation policies with association to rice cultivation as a main water consumer crop in Egypt.

4.5.2 *Irrigation policy in Egypt*

Water is a finite resource that is fundamental for agriculture, industry, and human existence (Wichelns, 2002). In arid and semi-arid countries, where water resources are very limited, achieving the highest possible water use efficiency is particularly important (Amer *et al.*, 2005). There is a challenge to save and conserve water while providing necessary quantities to satisfy social and economic requirements as well as conserve the environment. However, due to the increase in population and associated rise in the standards of living and human economic and social activities, the demands of water are escalating (Amer *et al.*, 2005). As a result, decision-makers have adopted several planning tools to secure water allocation and distribution. Simulation and optimization mathematical models, for example, are proven methods of such planning tools.

While Egypt is administratively divided into 26 Governorates, control of the irrigation system is divided into 18 Central Directorates (CD); each CD represents the Ministry of Water Resources and Irrigation (MWRI) in the region and is responsible for managing all the water resources under the supervision of the Irrigation Sector (IS) in the Ministry's Headquarters. Each CD includes one or more General Directorates of Irrigation (GD). There are 27 GDs covering the Nile Delta and a number of valley governorates depending on the complexity of the local irrigation network. The boundaries of the GDs are defined by specific control structures on the irrigation network; therefore, they have rather different administrative boundaries to the governorates (Amer *et al.*, 2005).

El-kady *et al.* (2001) have argued that the integrated water policy in Egypt is based on three fundamentals:

- Increase the natural Nile discharges at the upper sources.
- Increase the water use efficiency in all sectors.
- Prevent pollution, including non-conventional water sources.

In this context, it is important to refer to government policy towards rice production especially in the Delta. A variety of factors determine the area of rice cultivation, and the most important factor is the availability of irrigation water, as rice is one of the most water consuming crops. The average annual rice area reached about 0.59 M ha (1.4 M feddans) during 1994-1996. However, the long-term policy of the Ministry of Public Work and Water Resources (MPWWR) recommends that rice area should not exceed 0.3 M ha (0.71 M feddans) in order to balance the future expected water supply and requirements. Therefore, the only way to increase rice production in Egypt will be through vertical expansion programmes.

The government policy elements which have been used for developing rice production include:

- Ensuring good availability of irrigation water in the most favourable areas and cultivate the best varieties suitable to each type of soil.

- Providing high yield rice varieties and the latest modern cultivation technology and farm husbandry including the use of mechanization.

- Supporting adaptive research aiming to improve yield and quality of rice.

- Provision of quality extension and supporting technology transfer programmes.

- Intensive and sustainable training for all parties concerned with rice improvement, namely; researchers, extension staff and rice farmers.

- Ensuring availability of farm inputs (quantitative and qualitative).

In addition to the policies described above, rice production has also been affected by the changes in agricultural policy after the implementation of the economic reform programme. A comparison by Sabaa and Sharaf (1998) was made between two periods, 1985-1990 (before liberalization) and 1991-1996 (after liberalization). The following results were obtained:

- The average annual rice area increased by 34%, yield by 26%, production by 70% and cost of production by 146%.

- The average net return per hectare increased from LE 817 to LE 2051 (151% increase).

Further investigation is required to assess to what extent the changes in agricultural policies associated with rice cultivation have played an important role as a response in land-use change. The discussion and analysis of rice area, production, yield and prices, will, therefore, be presented in the next section.

4.5.3 Rice production in the Nile Delta: development and changes

This section will discuss the extent to which changes in agricultural policies associated with rice production have resulted in changes in land-use in the Nile Delta during the period 1984-2003. In the context of this study and the data available, the investigation will use agricultural census data for rice during the period 1985-1996, as rice is the most important crop associated with water consumption and irrigation policy development in the Nile Delta. Table 4.10 shows rice area, yield, production, cost, net return and return per capita in the Nile Delta during the period 1985-1996. These data were obtained from Department of Statistics, Central Administration of Agricultural Economics; Ministry of Agriculture. The most critical data in the table are the development of rice area during this period.

Year	*Area (ha)*	*Yield ($T\ ha^{-1}$)*	*Production (000 T)*	*Cost of Production ($LE\ ha^{-1}$)*	*Net return ($LE\ ha^{-1}$)*	*Return Per Capita*
1985	388223	5.95	2310	821	524	0.64
1986	423443	5.77	2444	907	624	0.69
1987	412210	5.83	2404	1009	300	0.3
1988	351702	6.06	2131	1054	602	0.57
1989	412813	6.48	2676	1131	1323	1.17
1990	435439	7.27	3166	1242	1528	1.23
1991	462042	7.46	3446	1652	1711	1.04
1992	510305	7.66	3909	1994	1590	0.8
1993	538567	7.72	4159	2649	1390	0.52
1994	574671	7.92	4551	2792	2159	0.77
1995	582542	8.1	4755	2993	2533	0.85
1996	590336	8.35	4929	3112	2920	0.94

Table 4.10: Rice area, yield, production, cost, net return and return per capita in the Nile Delta during the period 1985-1996

(Source: Dept. of Statistics, Central Administration of Agricultural Economics, MOA, 2002).

Figure 4.7 shows rice area development during the period 1985-1996 in the Nile Delta. It can be seen from the graph that rice area increased from 388223 ha in 1985 to 412210 ha in 1987 with a change rate during that period 1.9% a year. On the other hand, and after the agricultural policy reform took place in the year 1986/1987, the rice area increased from 412813 ha in 1989 to 590336 ha in 1996 with a rate of change 3.75% a year during that period. The graph also shows that there was reduction in rice area (351702 ha) in 1988 following agricultural policy changes in 1986/1987. This drop could be explained in light of agricultural policy changes. Farmers were cautious in the year after the new policy took place and needed to make sure that the new regulations would give them additional benefits if they continued to enlarge their rice area, or change from another crop to rice. Confidence in the policy grew and with it increased area of production in the following years, 1989-1996.

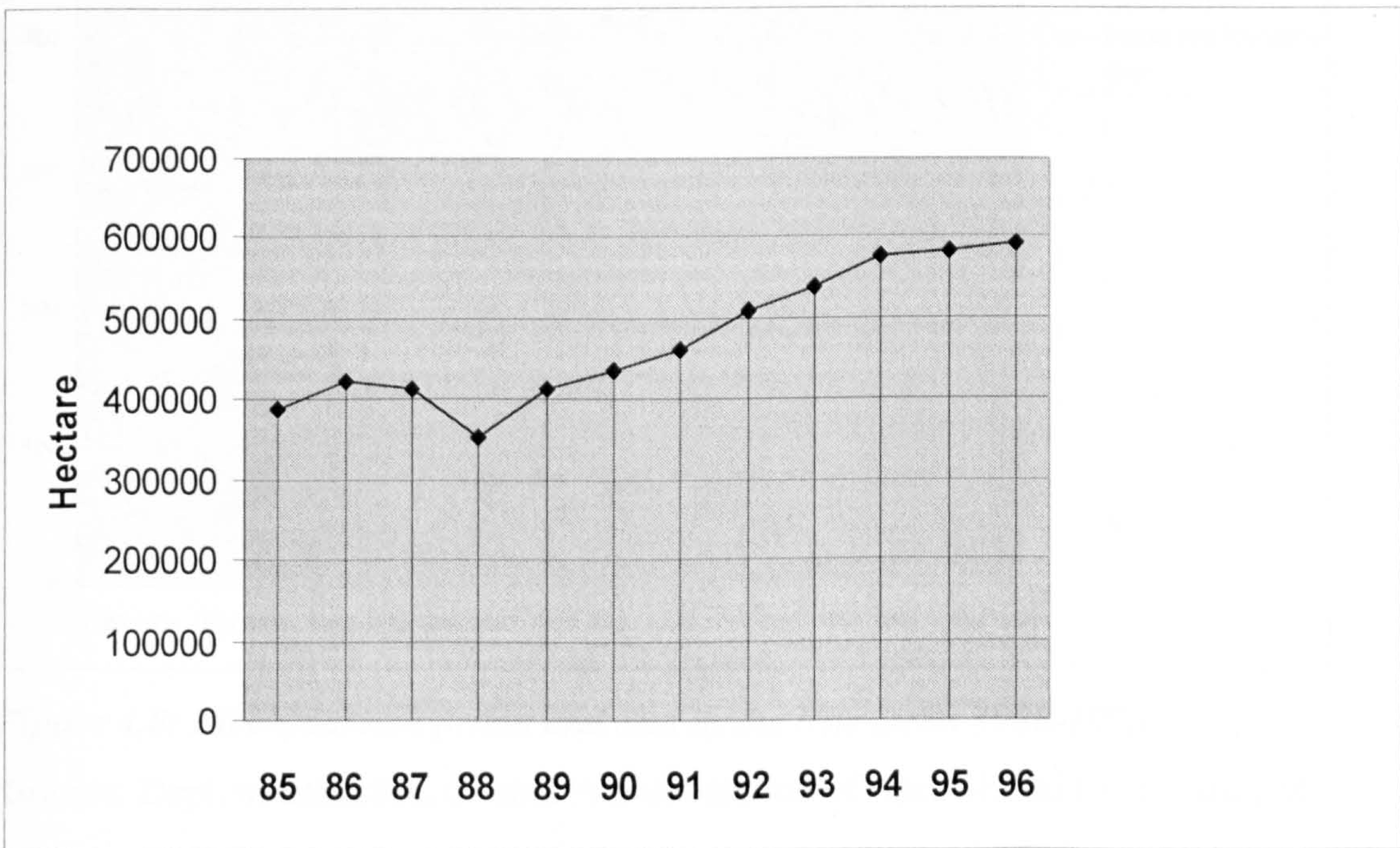


Figure 4.7: Rice area (ha) in the Nile Delta 1985-1996 (Source: Dept. of Statistics, Central Administration of Agricultural Economics, MOA, 2002).

As a result of these changes and agricultural policy reform, rice prices, yield and production also changed. Figure 4.8 shows current prices and cost for rice in the Nile Delta during the period 1980-1996. Figure 4.9 shows rice at constant prices and cost in the Nile Delta during the period 1980-1996. It can be seen from the graphs that, until the year 1985, the forced and floor prices of rice were lower than the cost of production. This means that farmers were losing money during this period.

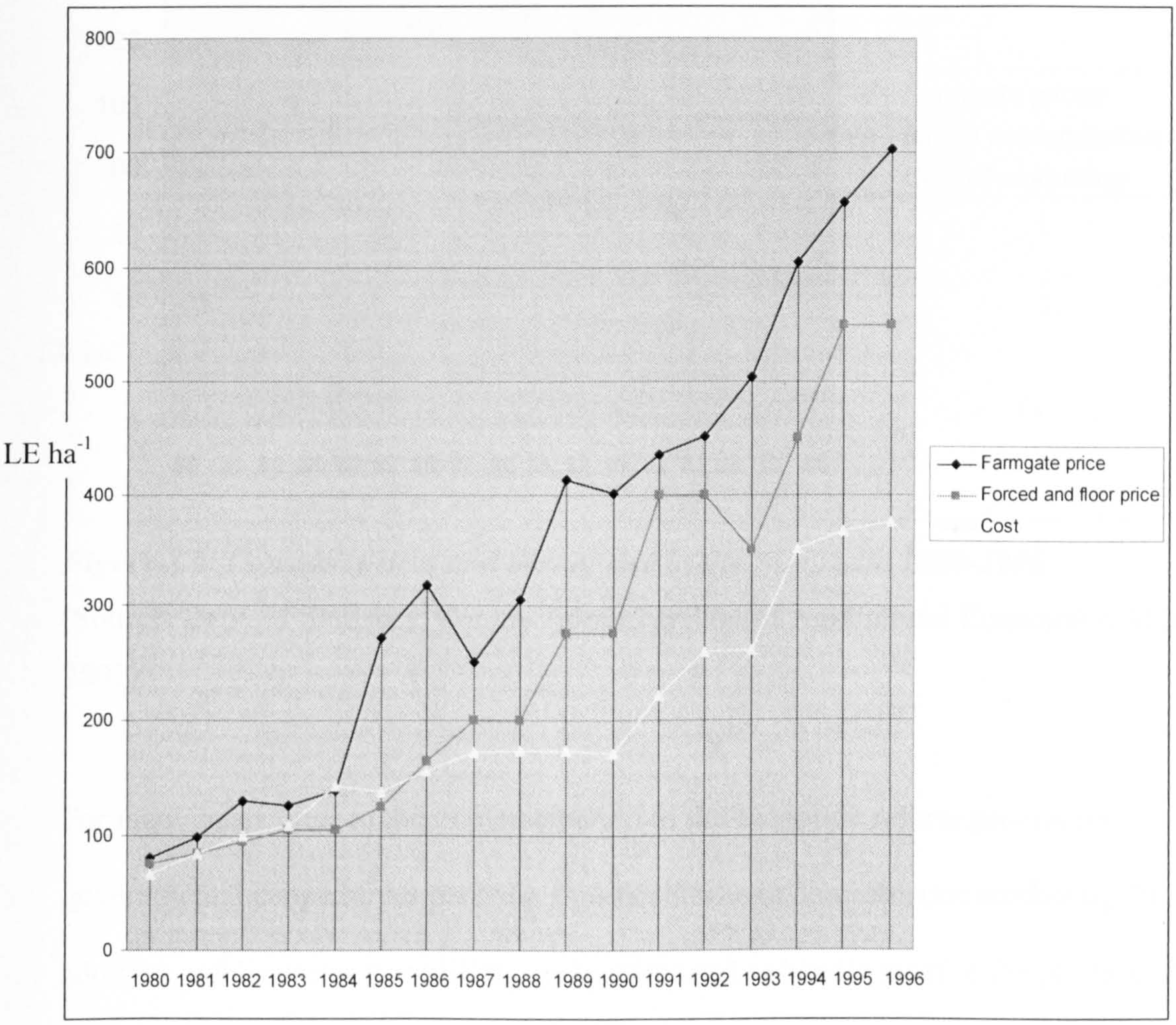


Figure 4.8: Rice's current prices and cost in the Nile Delta 1980-1996

(Source: Dept. of Statistics, Central Administration of Agricultural Economics, MOA, 2002).

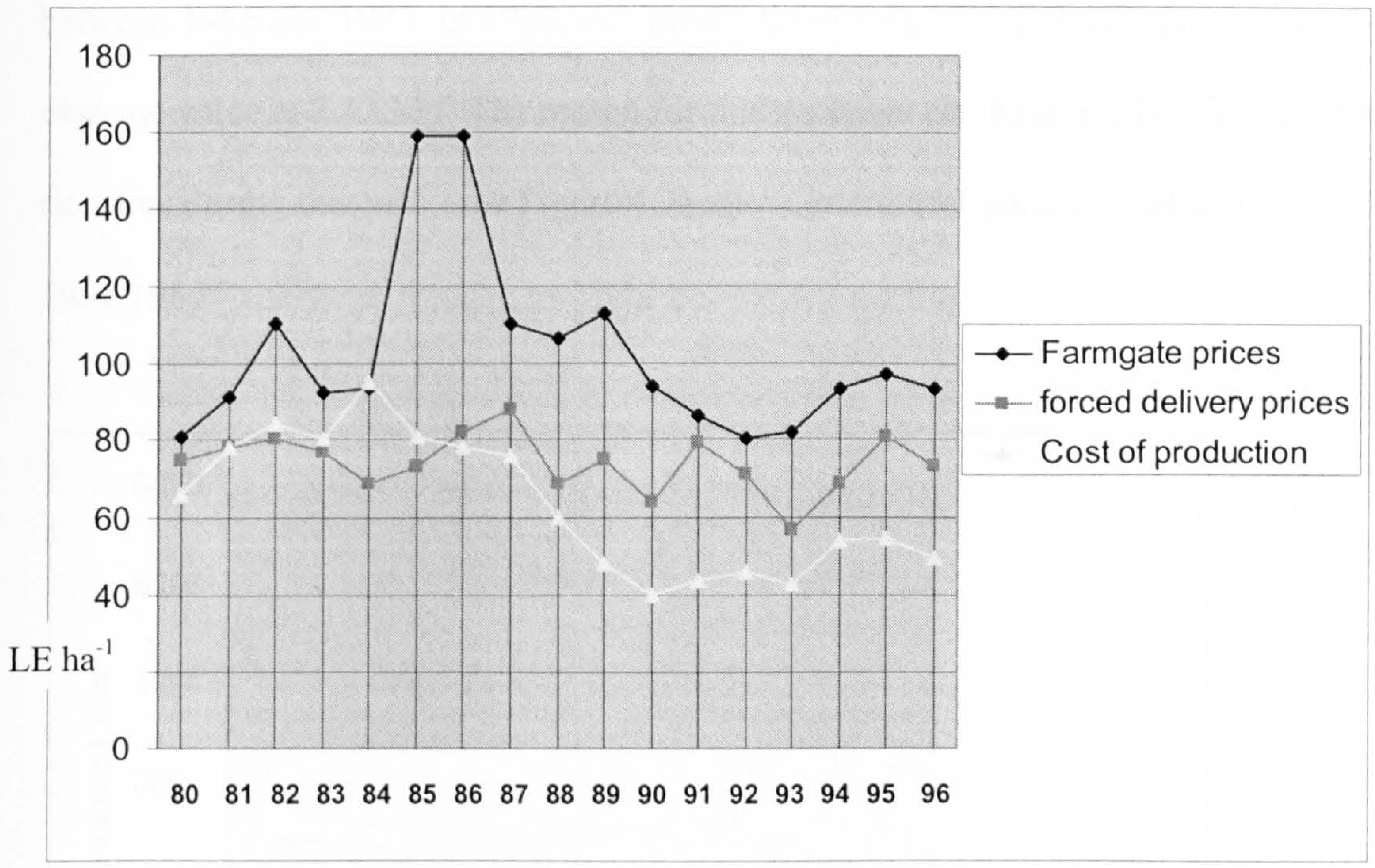


Figure 4.9: Constant prices and cost of rice in the Nile Delta 1980-1996
(Source: Dept. of Statistics, Central Administration of Agricultural Economics, MOA, 2002).

For many years prior to the implementation of the economic reform programme, governmental cooperatives played a significant role in domestic rice marketing. In addition, public sector rice milling companies used to handle most of the produce. A forced delivery system was applied through the agricultural cooperatives. Each rice grower was required to turn over 3.57 t ha^{-1} (1.5 tonnes per feddan) to the government at a fixed price. The forced delivery quota represented about 65% of the average yield per unit area at that time. Moreover, under the government control system, private sector companies and traders were not allowed to transfer rice between governorates or to export or import rice (Badawi and Mounir, 1998; Sabaa *et al.,* 1998).

Figure 4.10 shows rice production in the Nile Delta during the period 1985-1996; there was an increase in rice production between 1985 and 1986 followed by a decrease between 1986 and 1987. In 1988, rice production in the Nile Delta dropped to an extreme value at 2.13 M t. The reason for this decrease can be related to the decrease in rice area during this year (see Figure 4.7) after agricultural policies changed in 1986/1987.

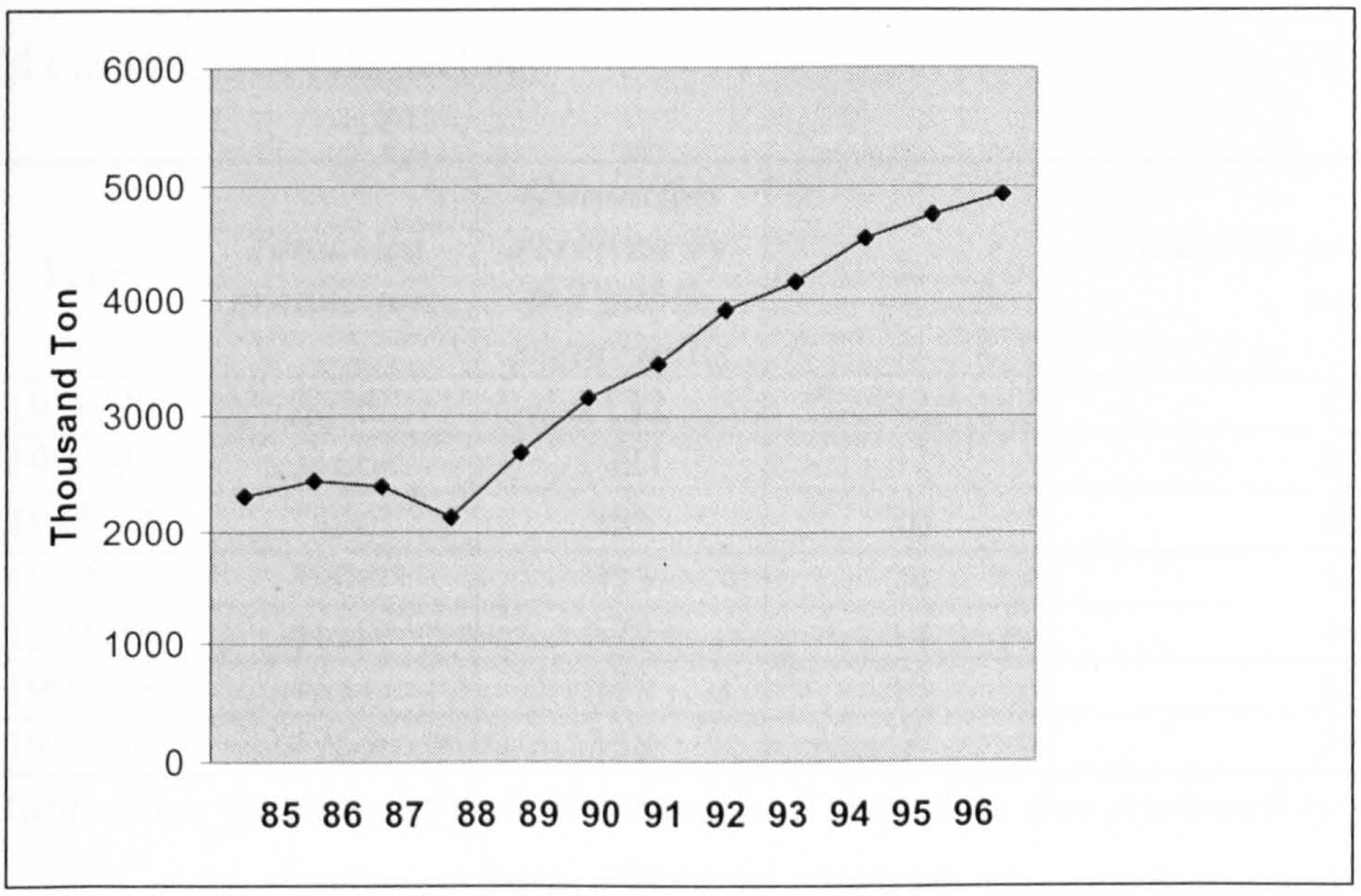


Figure 4.10: Rice production ('000 tons) in the Nile Delta 1985-1996
(Source: Dept. of Statistics, Central Administration of Agricultural Economics, MOA, 2002).

The rice marketing system changed in 1991 as follows:

- Alteration of the marketing system from the governmental cooperative marketing to the free market system. As of the 1991/92 season, rice producers were able to sell their production in the free market.
- Cancelling of the forced quota delivery regime.
- Free rice storage and transportation of rice among governorates.
- Private sector was allowed to play the largest role in rice marketing.

As a result of liberalizing the rice market, the relative importance of the public sector mills as a rice buyer decreased compared to the private sector. The percentage of rice quantities received by the public sector mills to the total production decreased from 42% in 1989/90 to 7% only in 1995/96 (Table 4.11). Similarly, the quantities of white rice produced by the public sector mills decreased from 0.69 M t in 1998/1990 to 0.38 M t in 1995/96 (44% decline).

Year	*Total rice production*	*Quantities received by the public sector mills*	*%*	*White rice produced by the mills*
1989/90	2676	1132	42	680
1990/91	3166	1021	32	652
1991/92	3446	886	26	601
1992/93	3909	923	24	590
1993/94	4159	572	14	468
1994/95	4551	579	13	363
1995/96	4755	338	7	378

Table 4.11: Quantity of paddy rice received and white rice produced by public sector mills ('000 tons) during 1989/90 -1995/96 (Source: Sabaa and Sharaf, 1998)

Under the government controlled system, the forced delivery prices were determined by the Ministry of Supply for the quota procured. Farmers were able to sell the remainder of their production at the free market prices or retain it for personal consumption. After the liberalization policy had taken place, rice price was determined through supply and demand forces. To avoid the expected market instability especially at the beginning of the liberalization period, the government decided to, indirectly, interfere with the rice market as a buyer and announced a floor price to ensure an equitable price for farmers received and to minimize the degree of risk in rice farm-gate prices. As the new free market system became operational, floor prices set by the government disappeared.

In summary:

- During the period 1981-1985, the average forced delivery prices were below the average cost per unit; farmers lost money from growing rice.

-During the period 1985-1990, producers' margin increased due to government increased the forced delivery price.

- From 1991 onwards, farm-gate prices, optional delivery prices and cost of production per unit appear to run at similar rates leaving a reasonable margin to the rice producer.

Figures 4.11and 4.12 show the development of cost of production and yield for rice in the Nile Delta during the period 1985-1996 respectively. It can be seen from Figure 4.11 that cost of production for rice experienced a slight increase every year between 1985 and 1990. However, starting from 1991, the cost of rice production experienced a dramatic increase. This increase can be explained in light of changes of subsidy policies in 1991 (see Table 4.9). As part of the agricultural policies change in 1991, the government decided to reduce input subsidies by a third and remove the exchange rate subsidy for imported inputs. These actions led to increased rice production cost. Rice yield as shown in Figure 4.12 experienced a slight decrease between 1985 and 1986 and started to increase between 1987 and 1996.

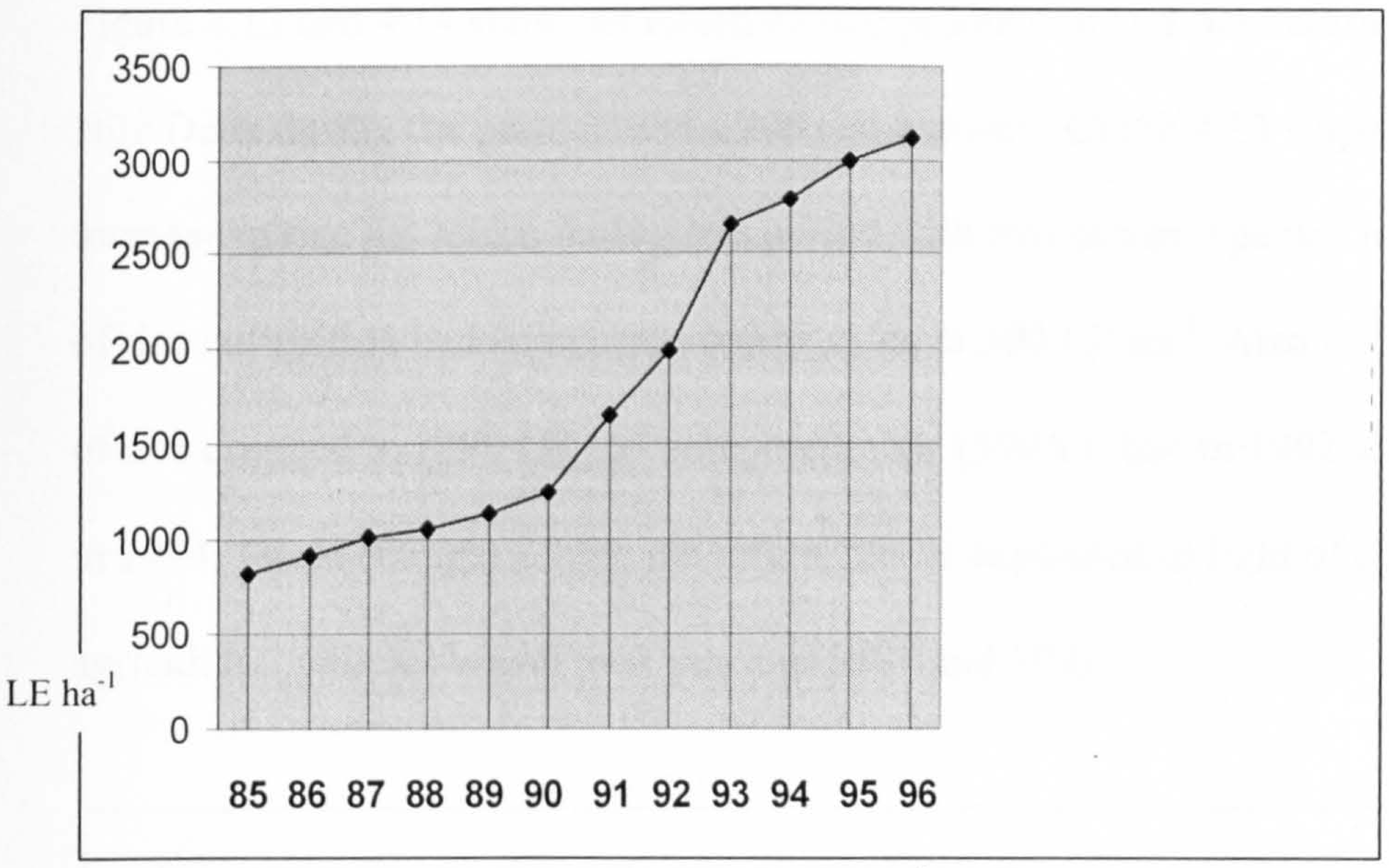


Figure 4.11: Cost of rice production (LE ha^{-1}) in the Nile Delta 1985 -1996

(Source: Dept. of Statistics, Central Administration of Agricultural Economics, MOA, 2002).

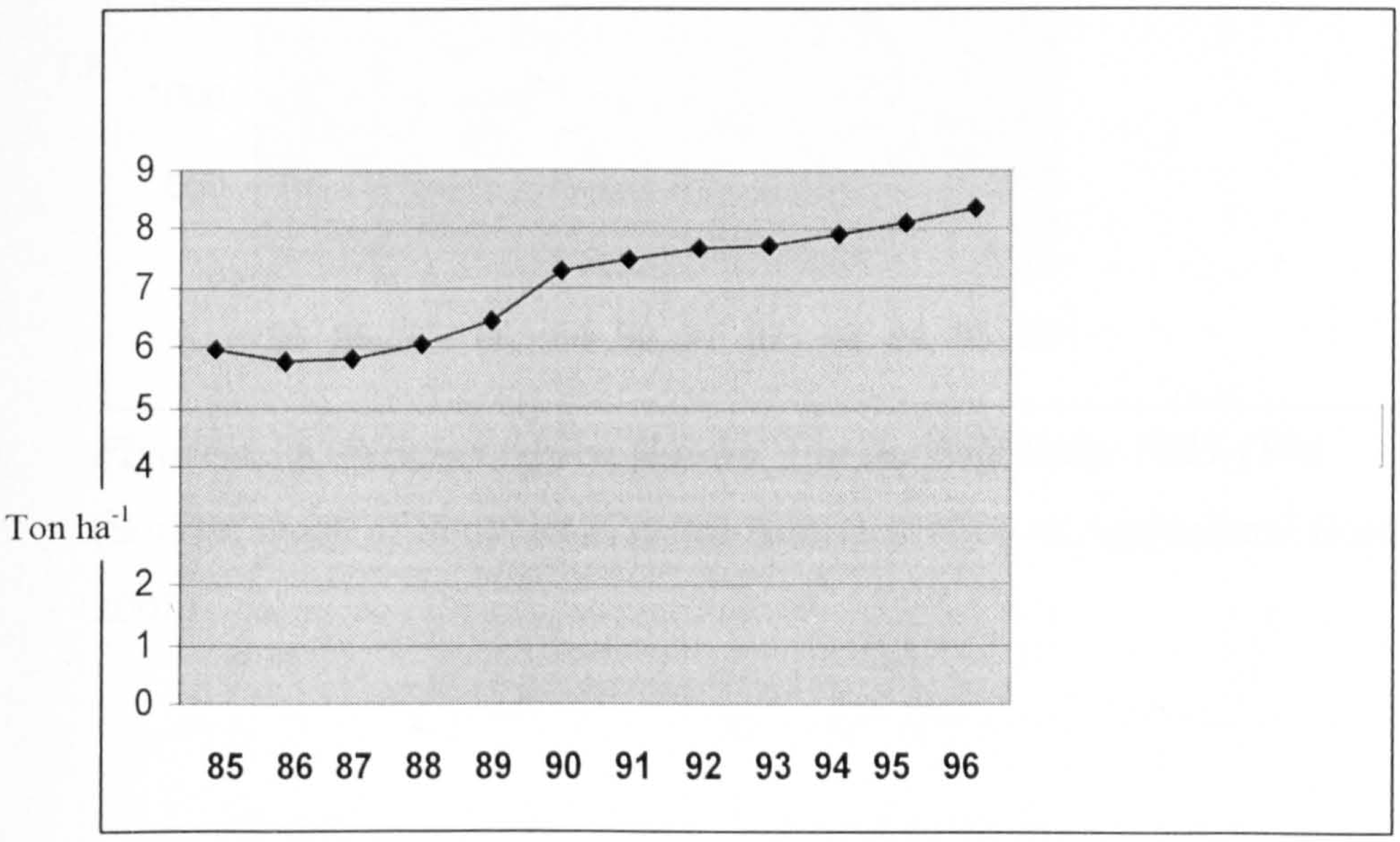


Figure 4.12: Rice yield (ton ha^{-1}) in the Nile Delta 1985 -1996

(Source: Dept. of Statistics, Central Administration of Agricultural Economics, MOA, 2002).

Figure 4.13 and 4.14 show net return of rice production and rice return per capita in the Nile Delta during the period 1985-1996 respectively. Graph 4.13 suggests a general increase in rice net return during this period with two extreme peaks. In 1987, net return of rice cultivation had an extreme lower value at 300 LE ha^{-1}. Also in 1993, net return of rice dropped to 1390 LE ha^{-1} compared with 1590 LE ha^{-1} in 1992 and 2159 LE ha^{-1} in 1994. These changes of rice net return can be explained in light of changes in agricultural policies which took place in 1987 and 1993.

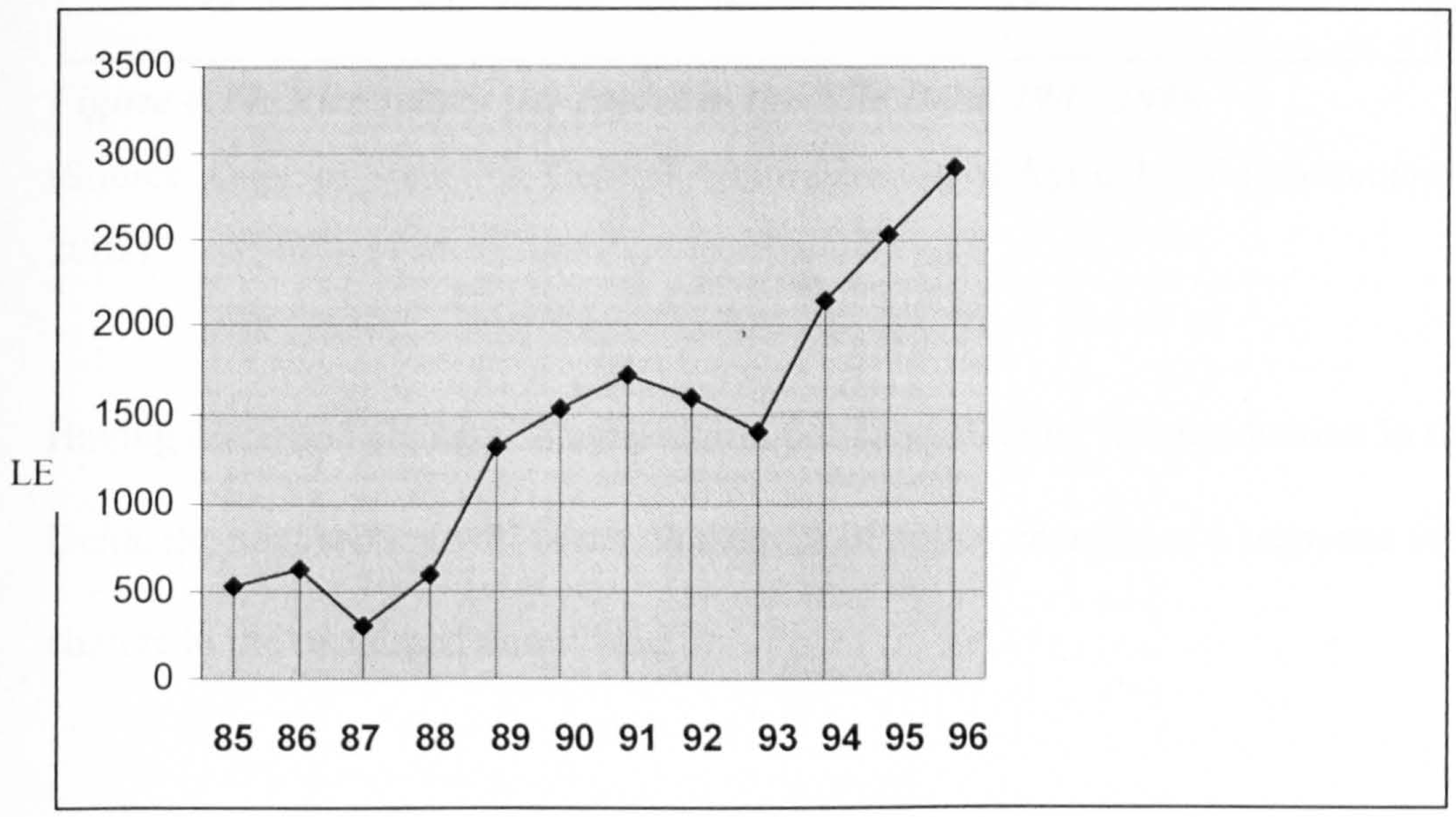


Figure 4.13: Rice net return (LE ha^{-1}) in the Nile Delta 1985-1996

(Source: Dept. of Statistics, Central Administration of Agricultural Economics, MOA, 2002)

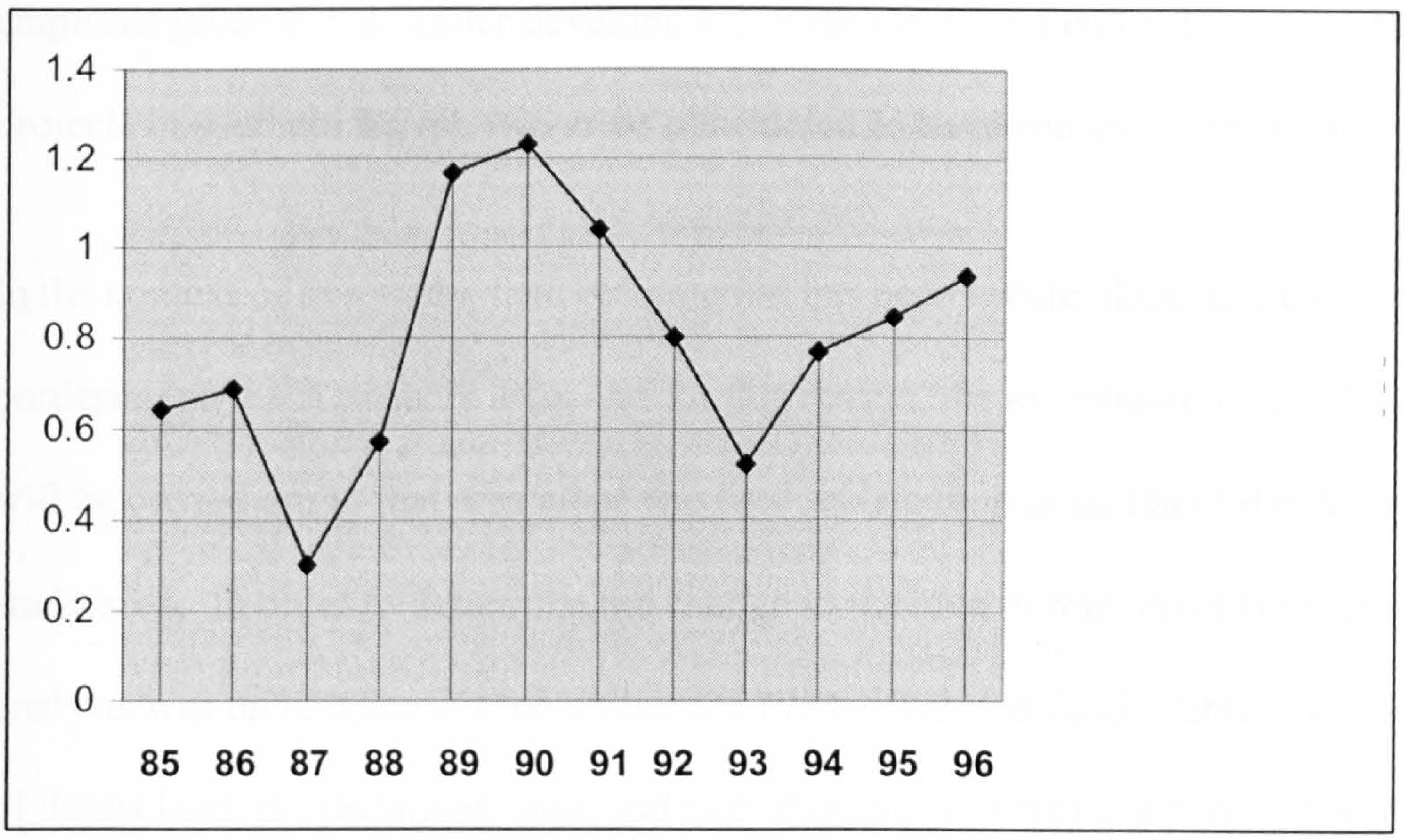


Figure 4.14: Rice return per capita in the Nile Delta 1985-1996
(Source: Dept. of Statistics, Central Administration of Agricultural Economics, MOA, 2002).

Having discussed changes in agricultural policies affecting rice production in the Nile Delta, the next section will focus on the role of policy changes as a response to land-use change in the reclaimed desert land.

4.5.4 Agricultural policies in the "new land"

"New land" in Egypt refers to all the land that has resulted from reclamation projects. The massive land reclamation efforts since 1947 have aimed at increasing the area of cultivable land. One of the essential goals of Egypt's agricultural policy was to redistribute the population and to make full use of the so far unexploited areas and natural resources available. About 0.34 M ha (0.80 M feddans) were reclaimed during the 1960s but only minimal amounts were added during the 1970s. However, by the end of the 1980s, the total number of new land added was about 0.74 M ha (1.77 M feddans) (Goueli, 1993). Great attention is presently directed to the new cities with special emphasis given to the master development plans for Sinai Peninsula and the Toshka projects in southern Egypt, two areas considered to have enormous economic potential.

In the context of this study, land reclamation has been taking place in the desert area bordering on the Alzaqazig area, and for this reason, the investigation of policy impacts will be carried out in that area alone (no land reclamation occurred in the Almansouah study area). In order to determine the change in the area of reclaimed land, image analysis was undertaken for the scenes for 1984, 1992 and 2003. Table 4.12 shows area of desert land, the reclaimed land, and rate of change during the period 1984-2003. Figure 4.15 shows the desert area decline during the same period.

Year	*Desert area (Hectare)*	*Reclaimed area*		*Rate of change (whole period)*	*Yearly change rate*
		Period	Hectare		
1984	15948	**1984-1992**	3368	21%	2.6%
1992	12580	**1992-2003**	359	2.9%	0.25%
2003	12221	**1984-2003**	3727	23.3%	1.2%

Table 4.12: Desert area, reclaimed land and rate of change in Alzaqazig 1984 -2003

(Source: ERDAS IMAGINE 8.7 image analyses)

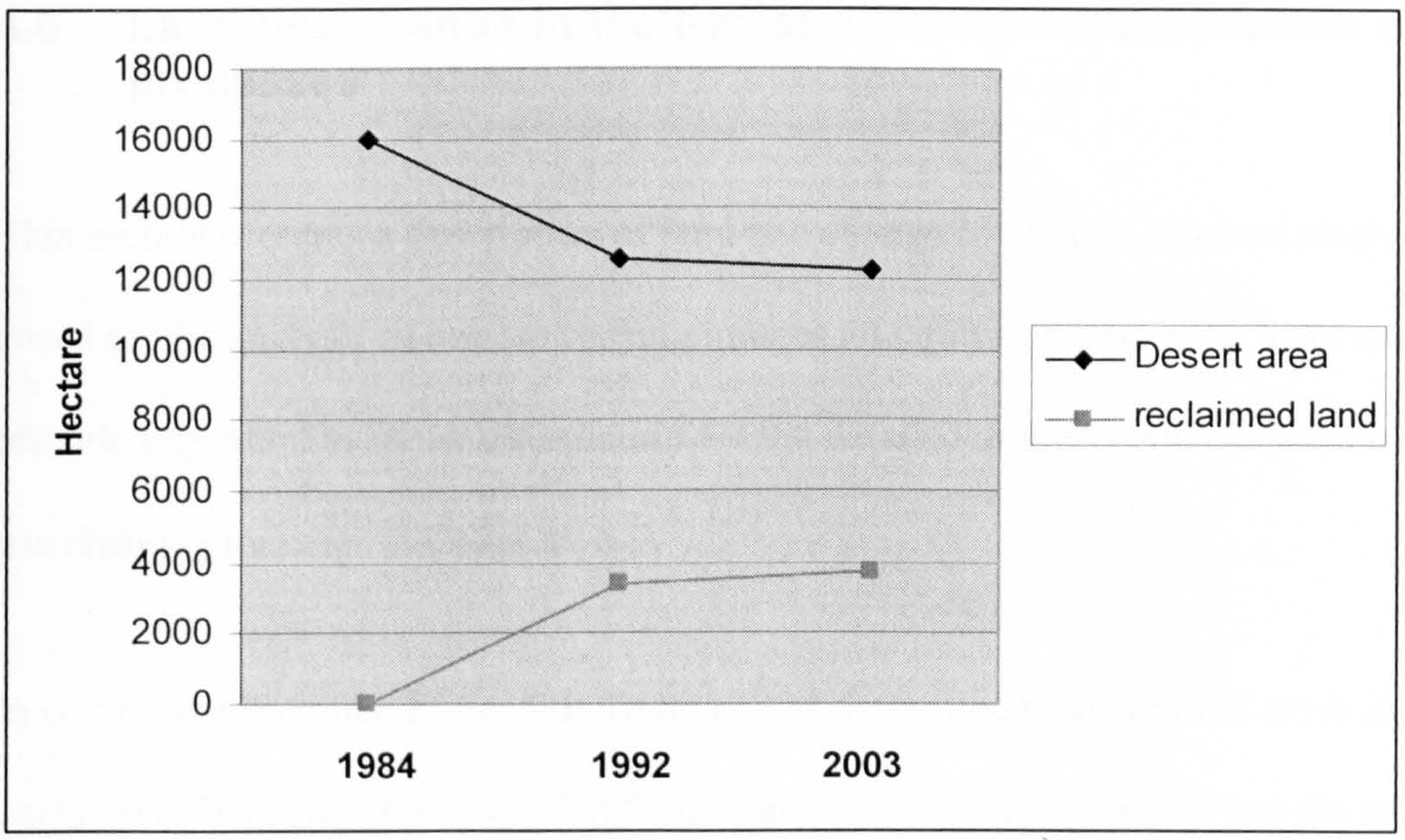


Figure 4.15: Desert area and reclaimed land in the Alzaqazig study area 1984 -2003
(Source: ERDAS IMAGINE 8.7 image analysis)

It can be seen from the table and graph above that the rate of land-use change from desert land into agricultural or settlement one was 2.6% a year (3368 ha over 8 years) throughout the period 1984-1992, and 0.25% a year (359 ha over 11 years) through the period 1992-2003. This means that there has been a minor amount of land reclamation during the overall period in the Alzaqazig study area despite the changes in the government agricultural policy. The reasons for those insignificant changes can be explained in light of the government efforts being directed to two giant reclamation projects, Toshka in the Southern Desert and Assalam in the Sinai Peninsula.

Having discussed the role of agricultural policies as a response to land-use change in the Nile Delta, the next section will describe key changes of land-use in the two study areas.

4.6 Land-use change in the two study areas: a description of key processes

This section presents a description of land-use change in the two selected study areas based on the analysis of remote sensing images and questionnaire data. This will provide important baseline information for the detailed analysis and discussion of land-use change processes in Chapters 6-9.

In common with much of the Nile Delta and as determined during field work in the two study areas between November 2005 and January 2006, it was found that the two dominant crops in winter (Figures 4.16 and 4.17) were wheat and Egyptian clover or Berseem with marginal fields cultivated by winter vegetables such as potatoes and broad beans (see Plates 4.1 and 4.2). In contrast, the dominant crops in summer were rice, cotton and maize (Figures 4.19, 4.20, 4.21 and 4.22) and marginal fields were cultivated with summer vegetables such as tomatoes and summer potatoes (Author's questionnaire, 2006).

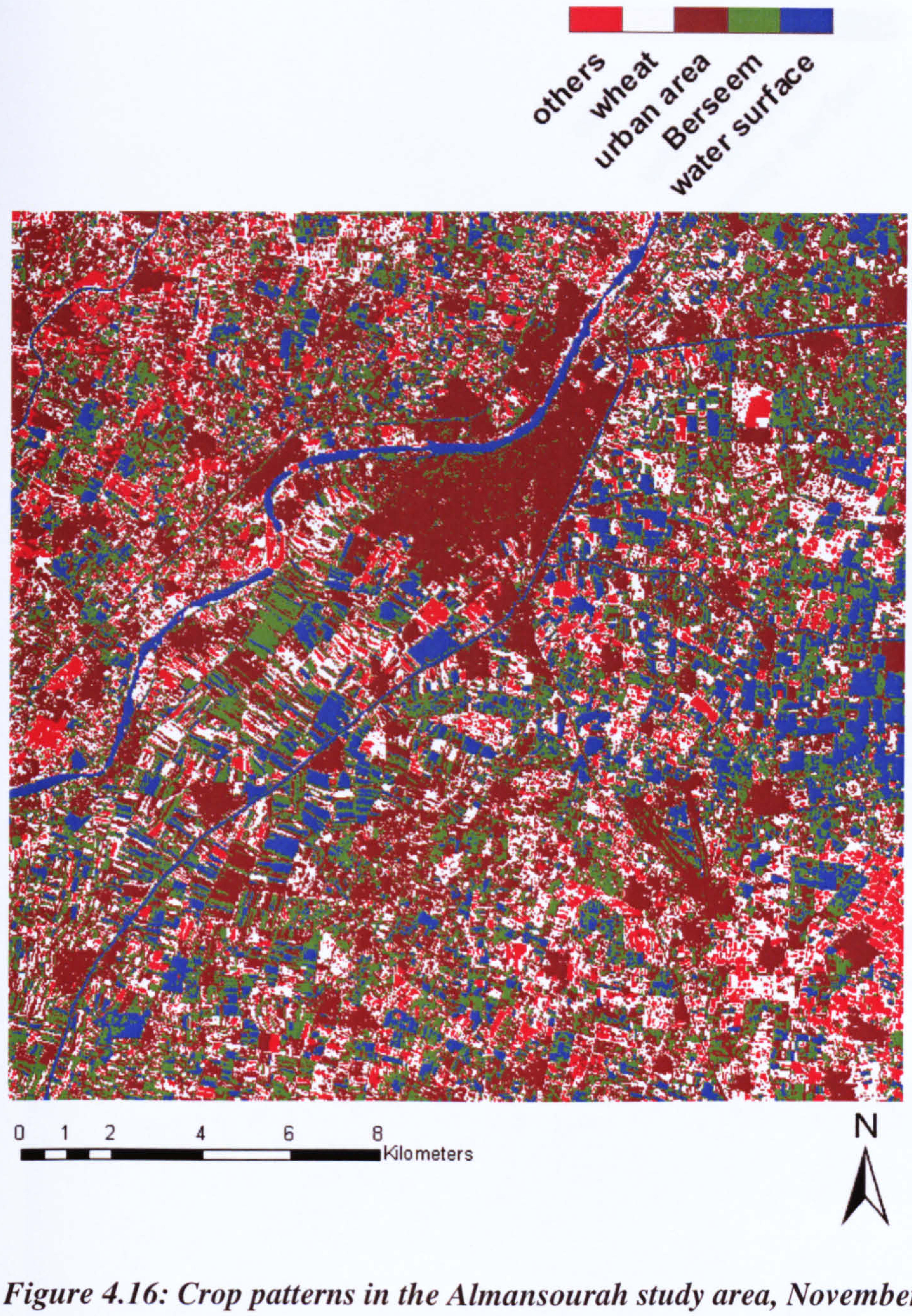


Figure 4.16: Crop patterns in the Almansourah study area, November 1992

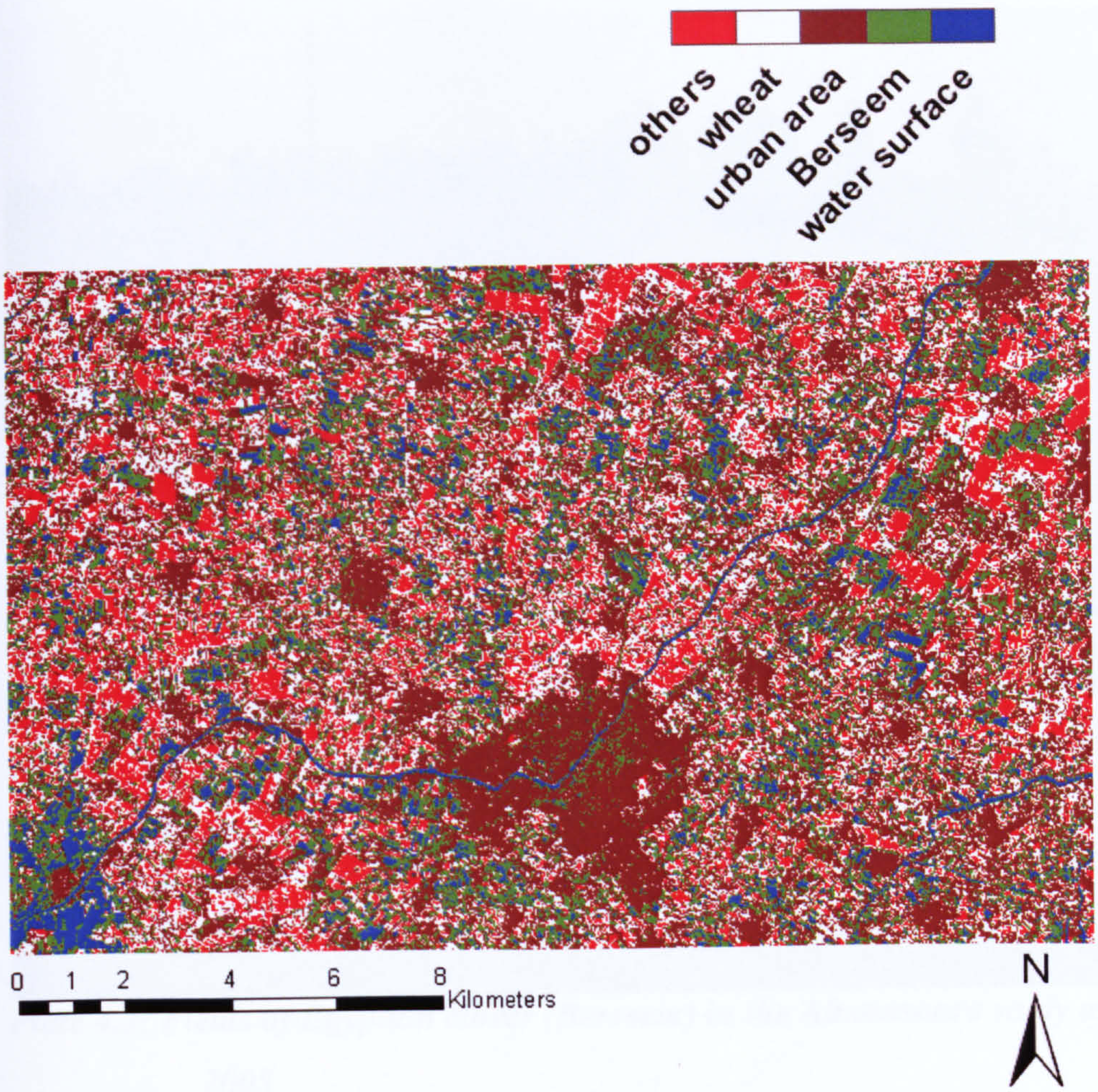


Figure 4.17: Crop patterns in the Alzaqazig study area, November 1992

Plate 4.1: Fields of wheat in the Alzaqazig study area, April 2005

Plate 4.2: Fields of Egyptian clover (Berseem) in the Almansoura study area, April 2005

The main aim of the satellite image analysis in the two selected study areas (Alzaqazig and Almansourah), as explained in Chapter 3, was to describe possible changes in crop patterns during the period 1984-2003 and to discover the possible reasons for these changes (see Chapters 6-9).

Based on these images, the total crop area in Almansourah study area increased during the period 1984-1992 and decreased between 1992 and 2003. In contrast, the total crop area in Alzaqazig study area decreased between 1984 and 1992 and increased during the period 1992 and 2003 (see Figure 4.18 and Table 4.13).

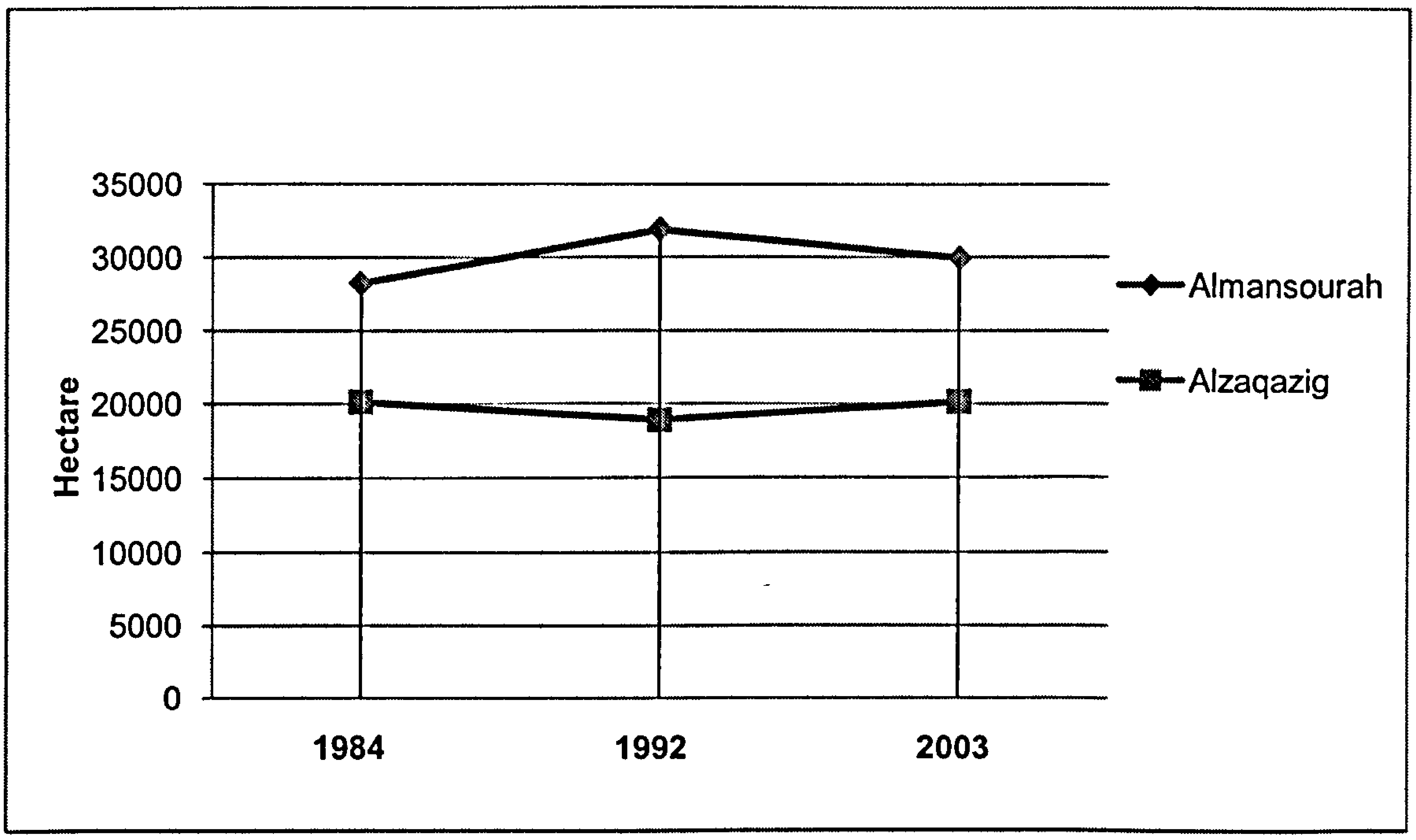


Figure 4.18: Crop area change in the two study areas (Almansourah and Alzaqazig)
(Source: ERDAS IMAGINE 8.7 images analysis)

Year	*The Almansourah study area*			*The Alzaqazig study area*		
	Hectare	*%Yearly Change rate of the total crop area*		*Hectare*	*%Yearly change rate of the total crop area*	
1984	28244.1	*84-92*	1.6%	20134.6	*84-92*	-0.8%
1992	31854.2	*92-03*	-0.5%	18883.7	*92-03*	0.61%
2003	29958.4	*84-03*	0.3%	20148.6	*84-03*	0.004%

Table 4.13: Total crop area change rate in the two study areas (Almansourah and Alzaqazig) (Source: ERDAS IMAGINE 8.7 images analysis)

Figures 4.19 and 4.20 show the distribution of crops in 1984 and 2003 for the Almansourah study area respectively. From these images some differences in crop patterns can be seen. Analysis of these images showed that there is a multiplicity of land cover at this time of the year and at least four or five types of crops such as rice, cotton, maize, summer vegetables and fallow fields were evident. Although the area of each type of land-use changed relatively little (Table 4.14), the remote sensing data show

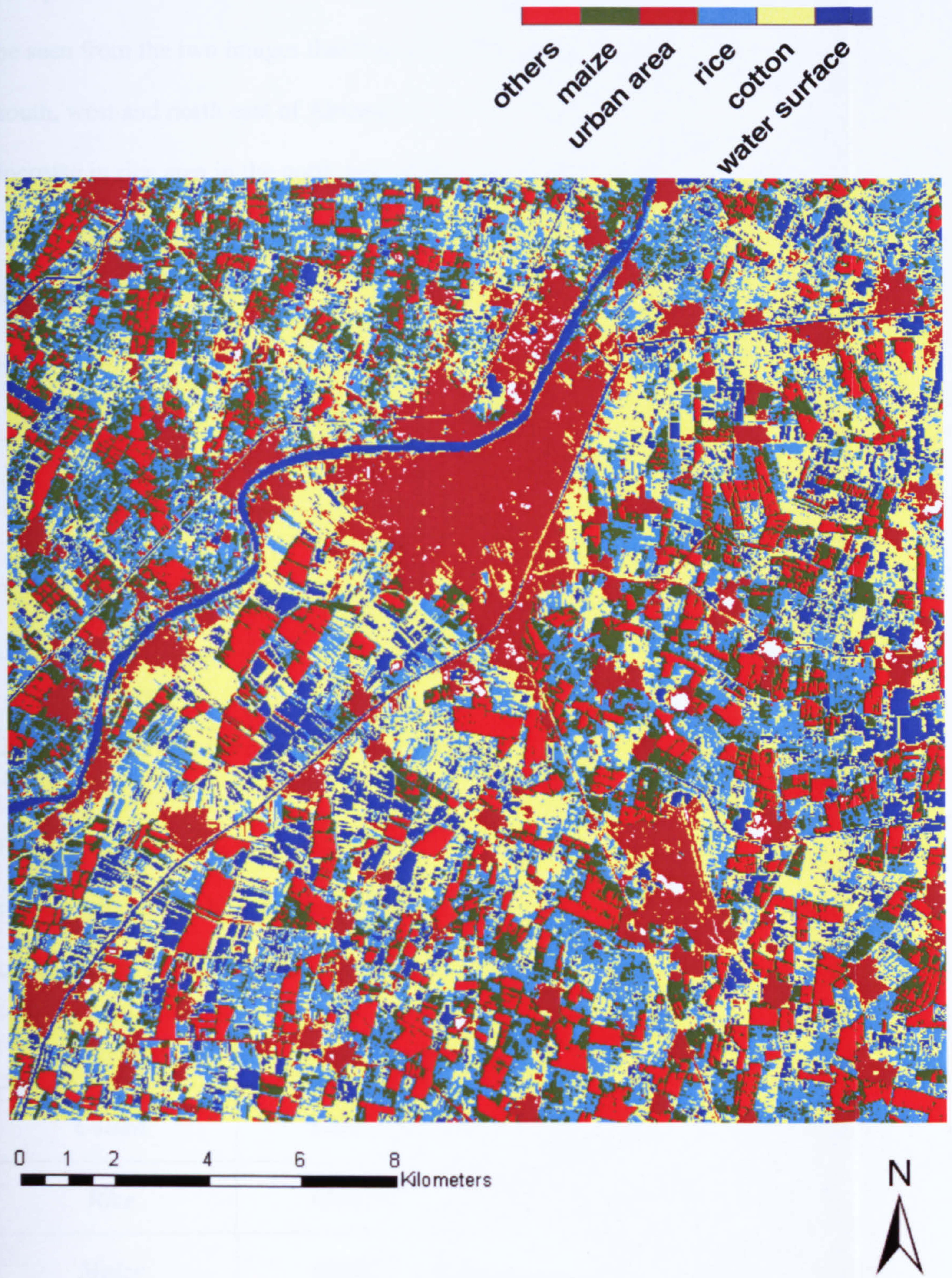


Figure 4.19: Crop patterns in the Almansourah study area, August 1984

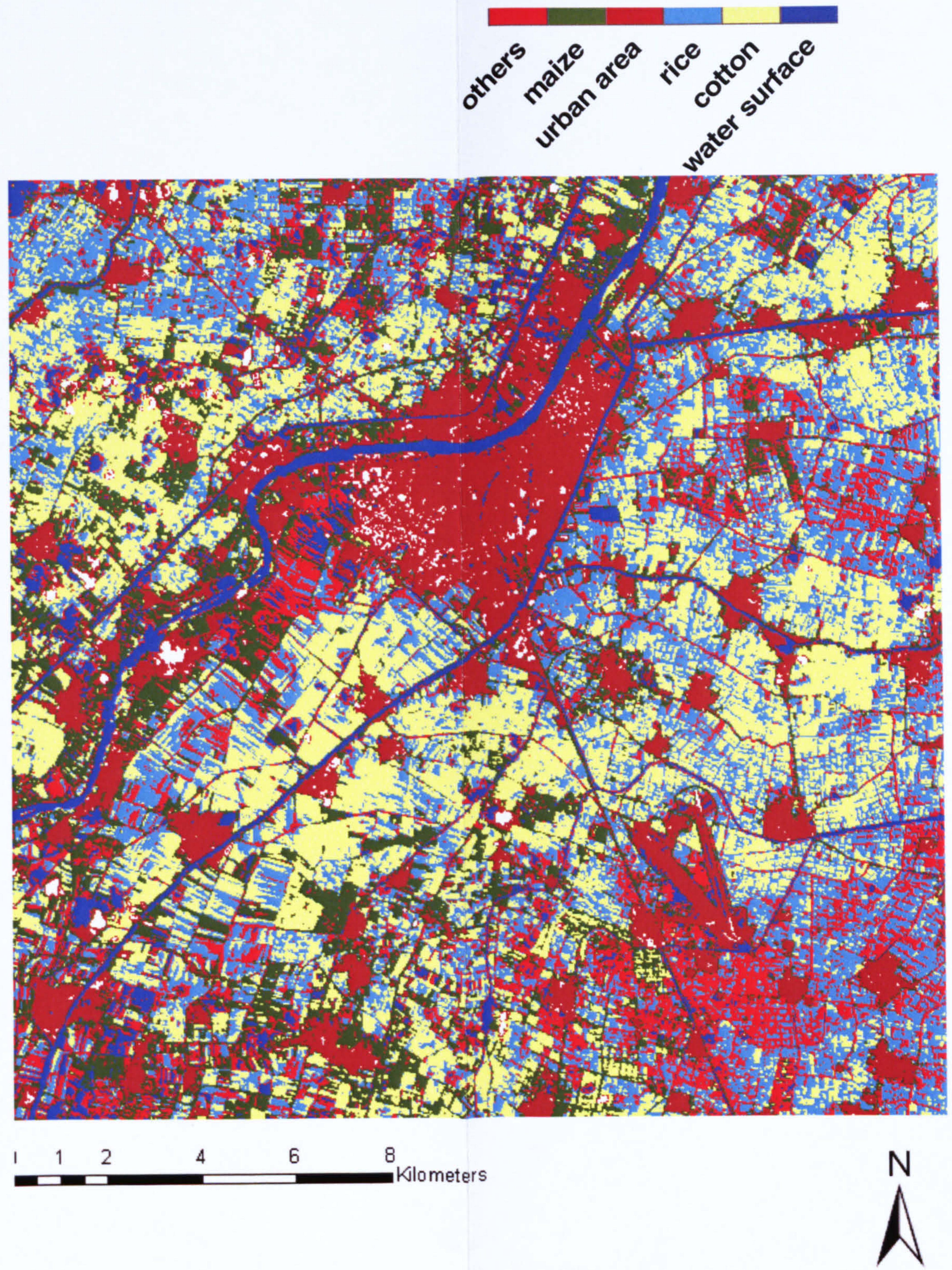


Figure 4.20: Crop patterns in the Almansourah study area, August 2003

some changes with regard to the geographical distribution of each crop. Using visual interpretation as a method used to analyse changes in land cover (see Chapter 3), it can be seen from the two images that there has been an increase in cotton area in the east, south, west and north east of Almansourah city. In contrast, with the exception of the increase in rice area in the north west and south east of Almansourah city, the area of rice decreased in general. The area cultivated with maize also decreased between 1984 and 2003 (Table 4.14).

Crop type	*The Almansourah study area*		
	1984 (hectare)	*2003* (hectare)	*% change*
Cotton	9986.58	10355.4	**+3.7**
Rice	10022.94	9059.67	**-9.6**
Maize	6107.76	5612.85	**-8.1**
Others	5140.8	4823.19	**-6.2**

Table 4.14: Crop area change in the Almansourah study area between 1984 and 2003

Figures 4.21 and 4.22 show crop patterns in the Alzaqazig study area in 1984 and 2003 respectively. It can be seen from the images that there also have been changes in land cover classes in this area during the period 1984-2003 (Table 4.15). This result was

Crop type	*The Alzaqazig study area*		
	1984 (hectare)	*2003* (hectare)	*% change*
Cotton	8269.02	8551.89	**+3.4**
Rice	6668.55	6883.74	**+3.2**
Maize	4013.73	3939.12	**-1.9**
Others	2807.55	2937.69	**+4.6**

Table 4.15: Crop area change in the Alzaqaig study area between 1984 and 2003

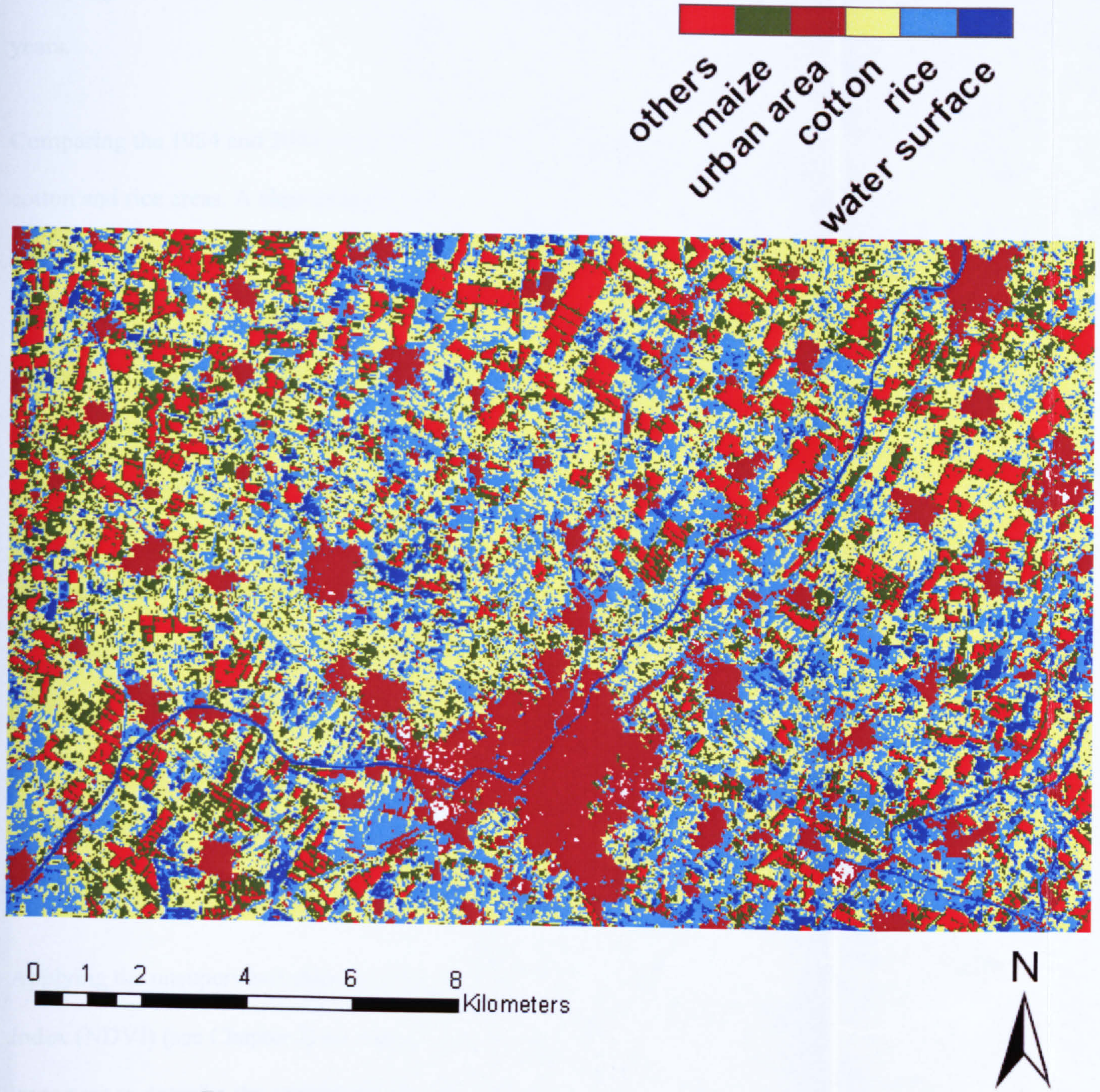


Figure 4.21: Crop patterns in the Alzaqazig study area, August 1984

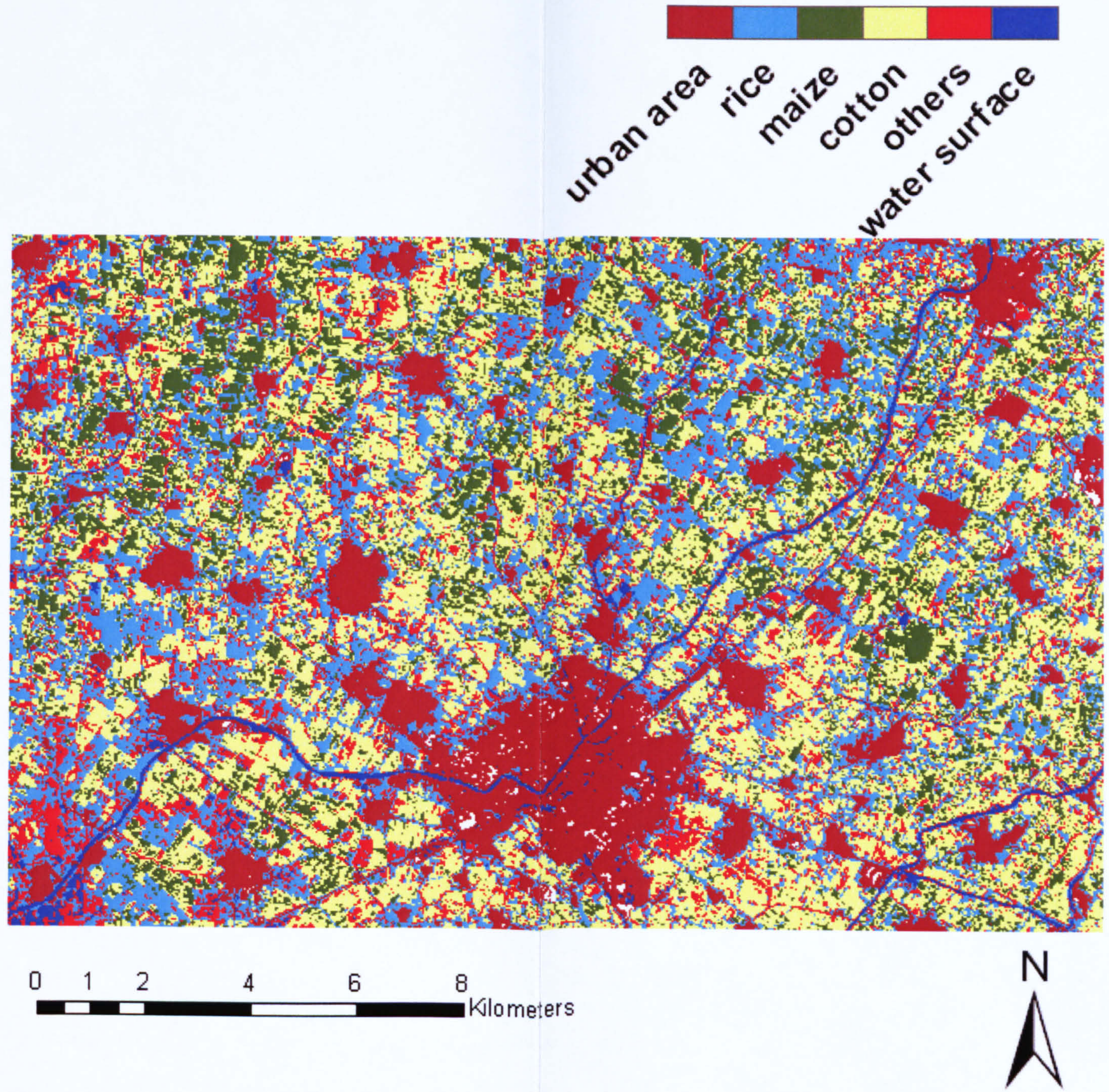


Figure 4.22: Crop patterns in the Alzaqazig study area, August 2003

confirmed by questionnaire data analysis which showed that 65% of farmers in the Alzaqazig area stated that there has been a change in their crops type during the last 20 years.

Comparing the 1984 and 2003 images, key changes include in particular the increase in cotton and rice areas. A clear example of the area of cotton expanding at the expense of rice can be seen in areas near Alzaqazig city in the west, south and east where most fields of rice in 1984 were replaced by cotton in 2003. In contrast, the fields in the north east and north west of the Alzaqazig city have been converted from cotton and other crops in 1984 to rice in 2003. Maize area has also experienced some decrease during the period 1984-2003 (Table 4.15).

Analysis of the remote sensing images offers a powerful tool to study changes in land-use patterns. It is, therefore, important to explore field patterns in the two study areas at a larger scale between summer 1984 and summer 2003. Examination of Figures 4.21 and 4.22 found that rice is one of the major crops in the two study areas. For that reason, considerable attention is given to the rice crop in general (Section 4.5) and changes in rice fields in the context of crop pattern changes throughout the investigation.

Applying the unsupervised classification of the Normalized Difference Vegetation Index (NDVI) (see Chapter 3) on a sample of the satellite image from each study area is important to describe the possible changes between 1984 and 2003. Figure 4.23 shows fields in the southern part of the Almansourah study area in summer 1984, while Figure 4.24 shows a view of the identical part of the crop area sample in summer 2003. Looking at the top left corner and central part of the two images, the settlement area has increased noticeably during the period 1984-2003(see above). The crop patterns have

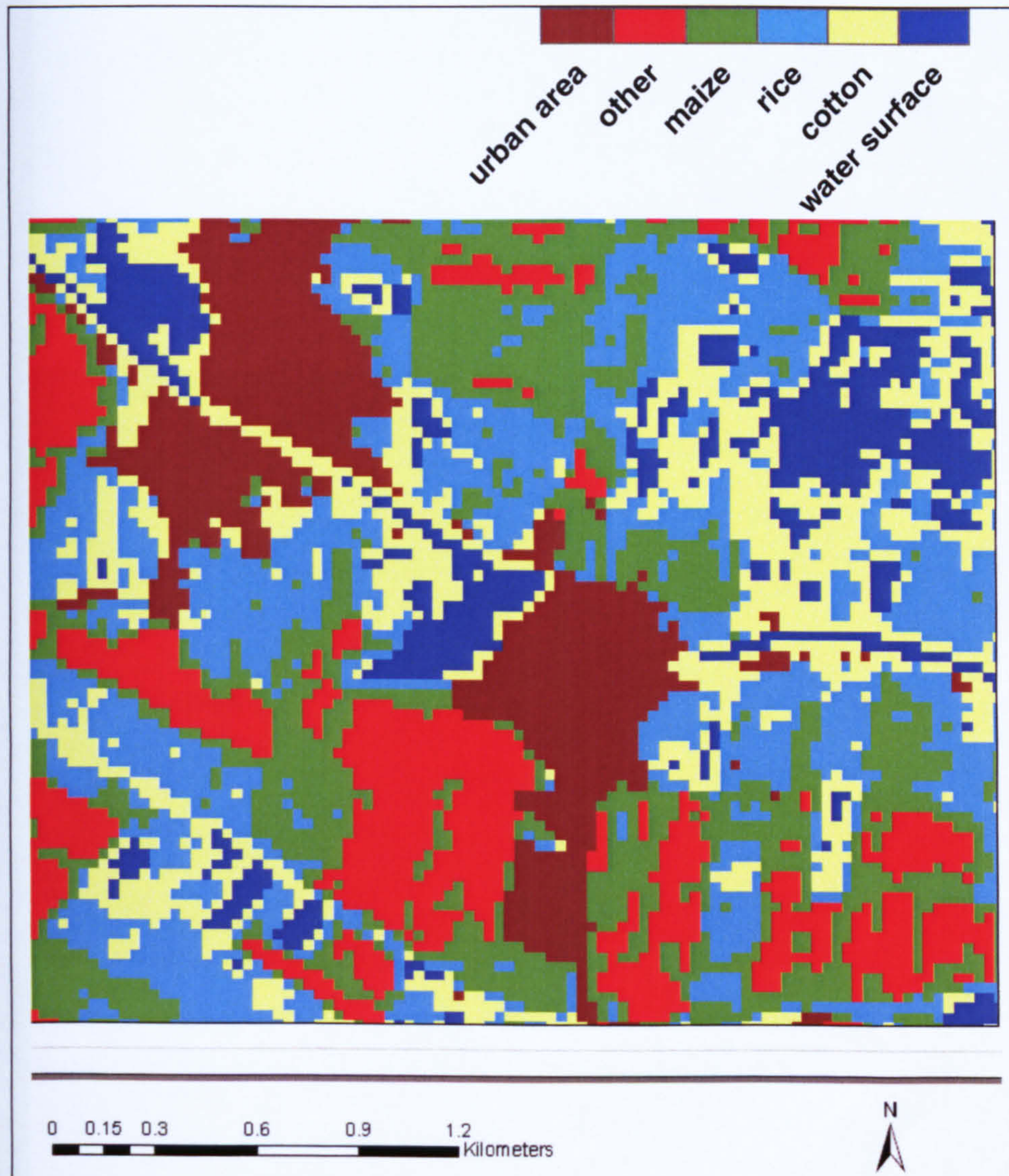


Figure 4.23: NDVI unsupervised classification for crop fields in the Almansourah study area, August 1984

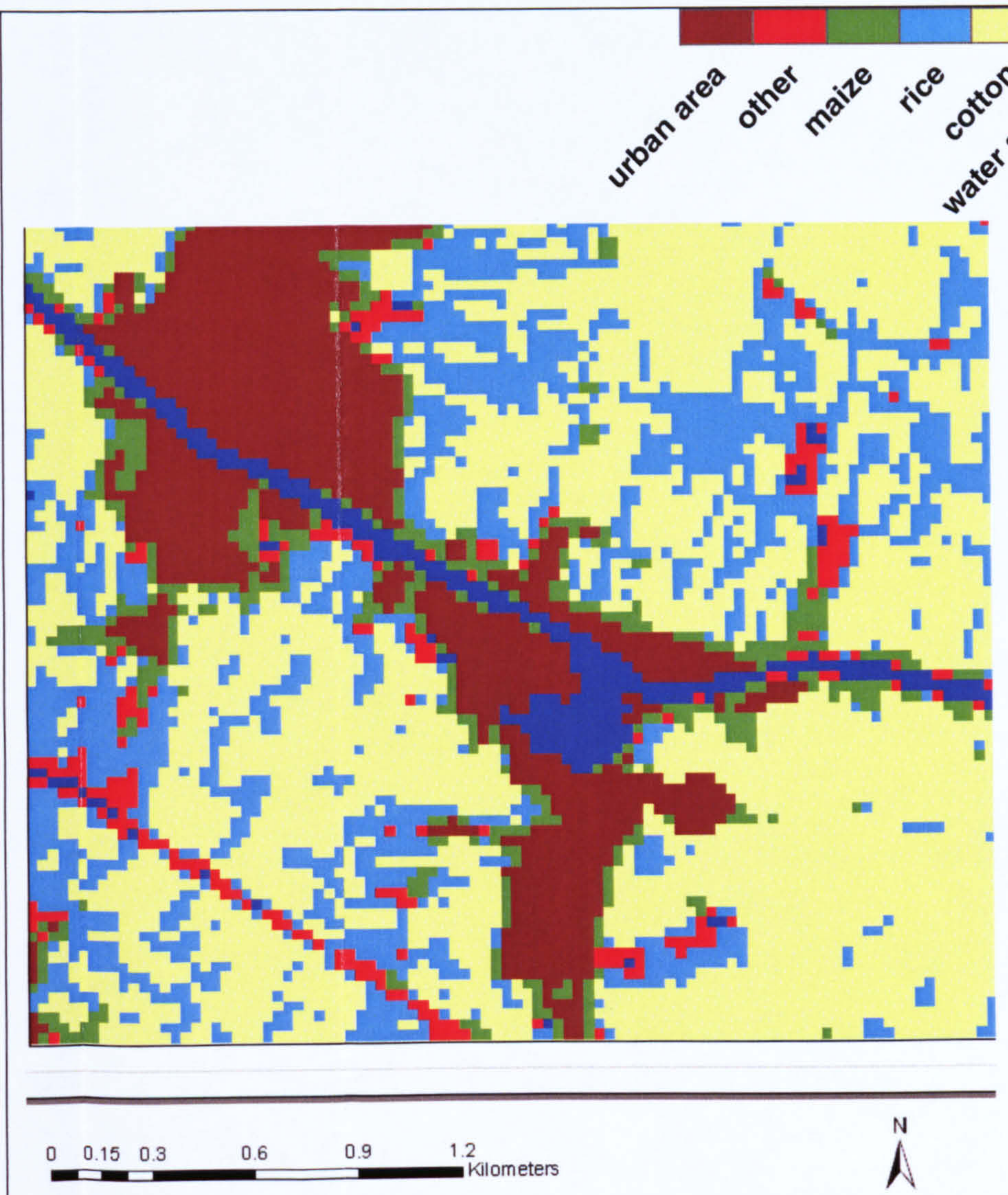
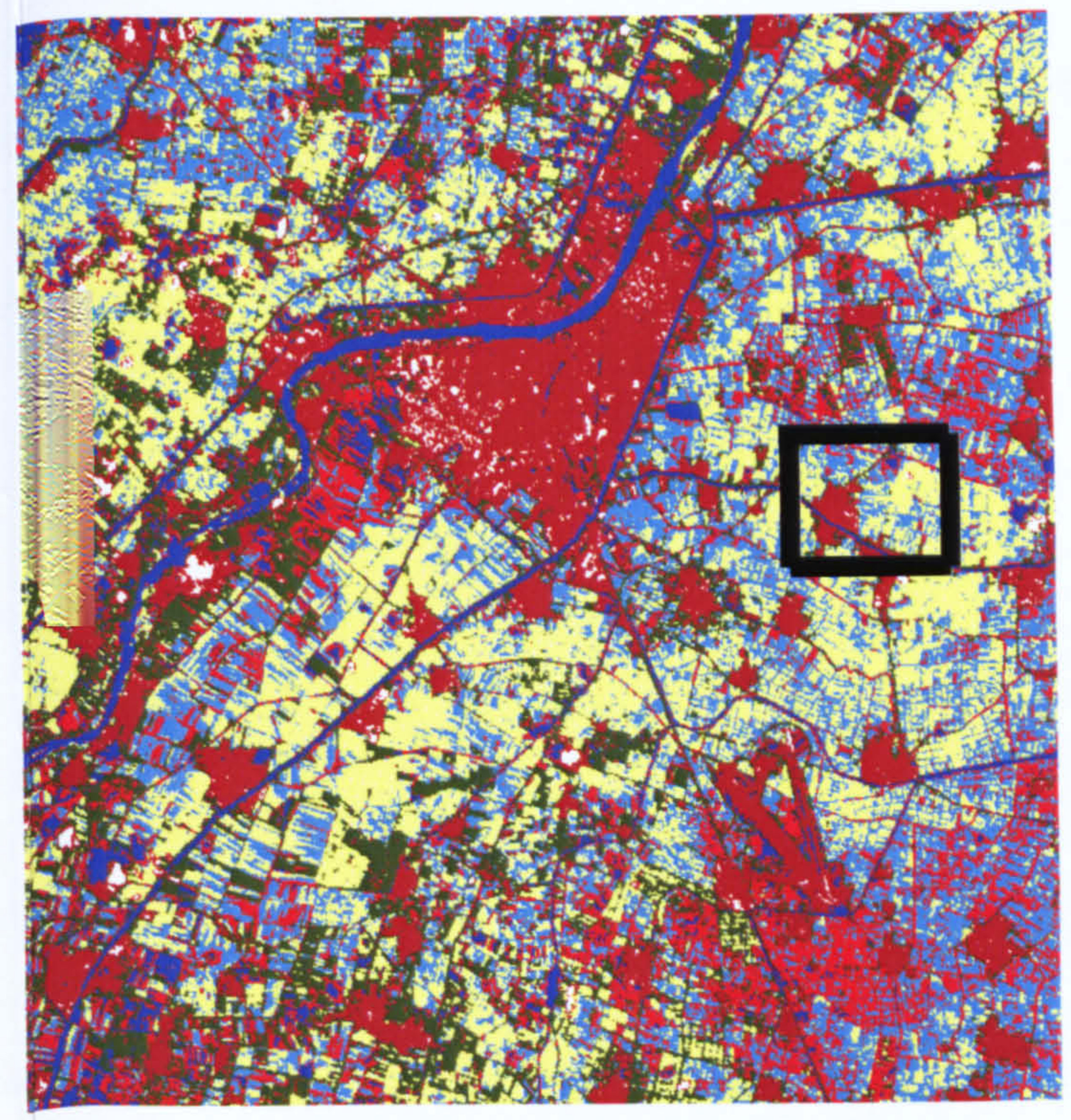


Figure 4.24: NDVI unsupervised classification for crop fields in the Almansourah study area, August 2003



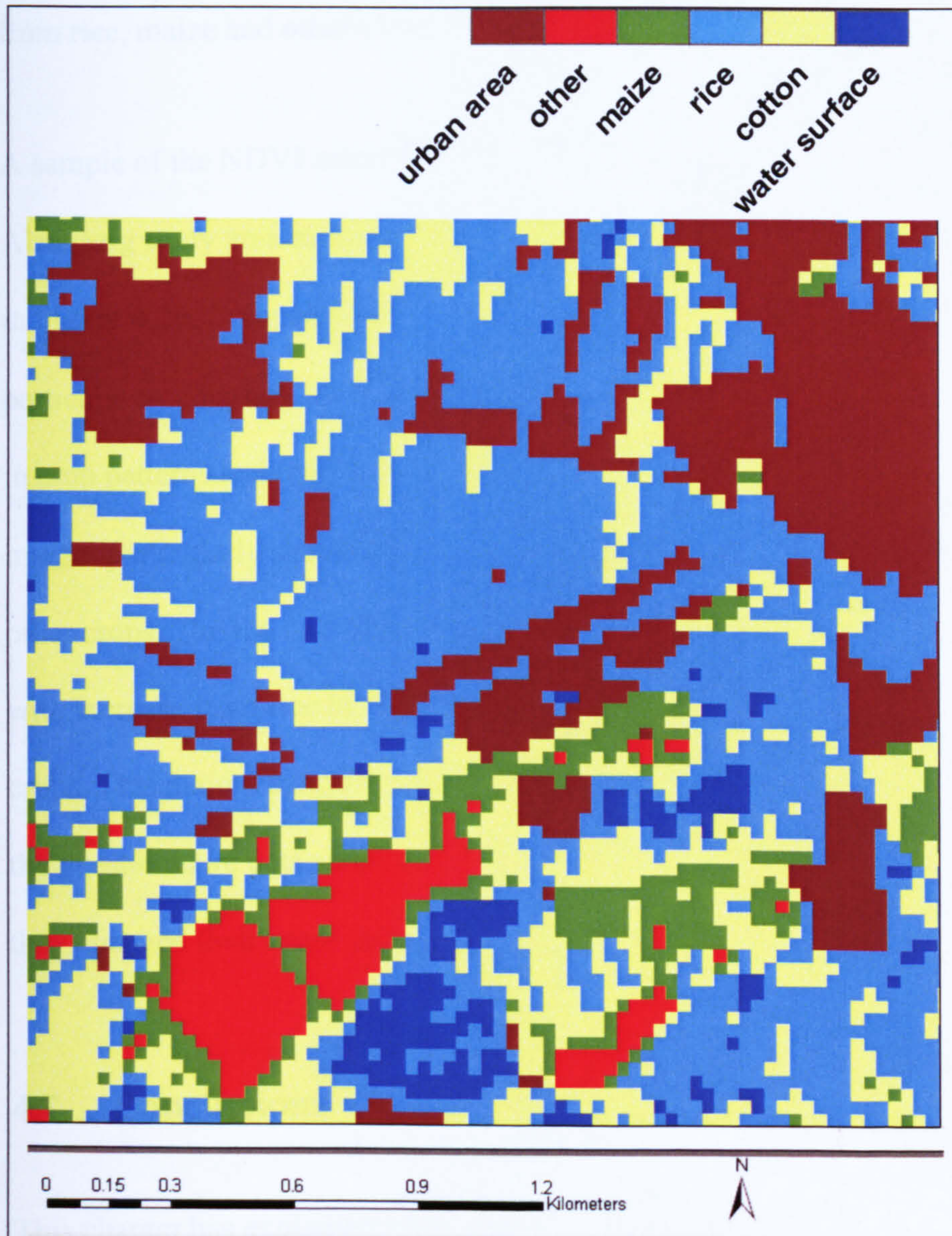


Figure 4.25: NDVI unsupervised classification for crop fields in the Alzaqazig study area, August 1984

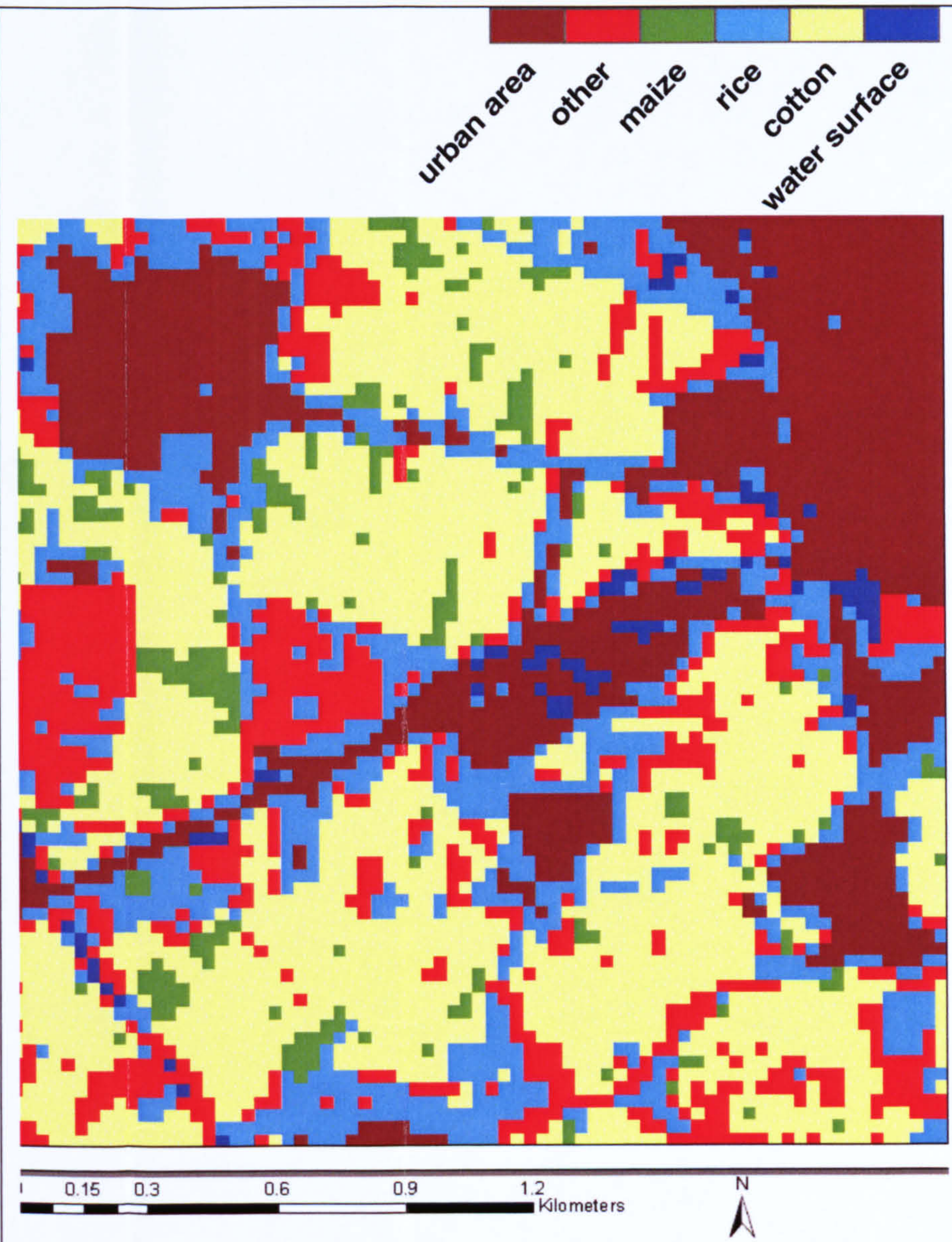
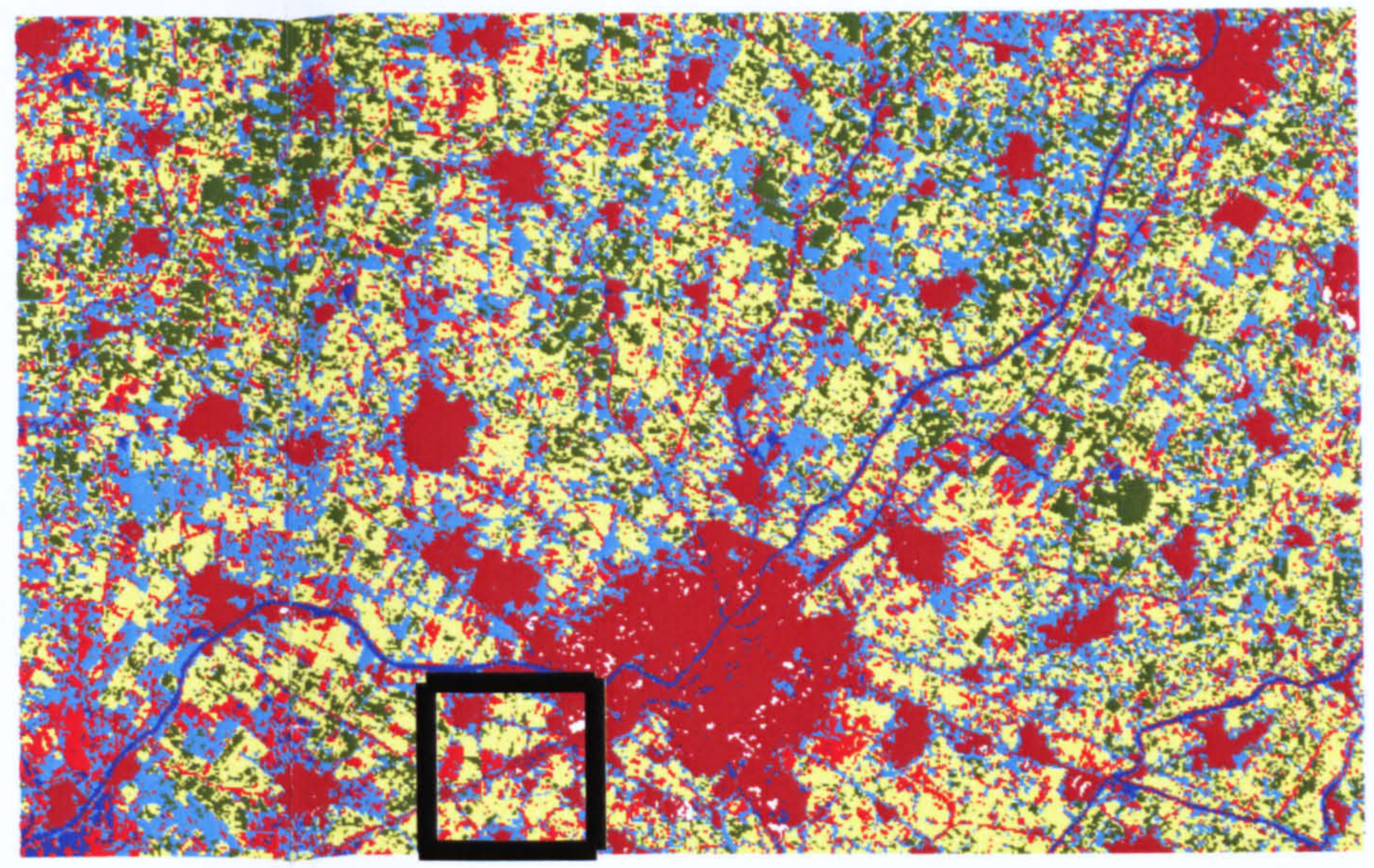


Figure 4.26: NDVI unsupervised classification for crop fields in the Alzaqazig study area, August 2003



experienced changes in many parts of the image during the period 1984-2003. These changes can be seen by focusing on the top right and lower right parts of the two images (i.e. much more cotton and less rice, maize and other crops). Similarly a major crop pattern change can be noticed in the central part of the scene which shows a change from rice, maize and other crops to cotton.

A sample of the NDVI unsupervised classification for fields in the southern part of the Alzaqazig study area in summer 1984 is presented in Figure 4.25 and for summer 2003 in Figure 4.26. Comparing the two figures shows the increase in urban settlement in particular by focusing on the top right corner of the two images. It also shows changes in crop patterns and crop types during the period 1984-2003. The lower half of the two images particularly shows the increase in cotton area at the expense of rice, maize and other crops. The top half of the images also highlights a major change during this period with increase from rice in 1984 to mainly cotton and some increase in maize and other crops. This major change in land-use in the Alzaqazig study area has been supported by the questionnaire data analysis, as almost two thirds of farmers in Alzaqazig confirmed they changed their crops during the period 1984-2003 (see Chapter 8 for more detail).

4.7 Conclusions

This chapter has explained that Egypt is a semi-arid nation and described the major land-use changes in the two study areas (Alzaqazig and Almansourah). It presented the physical, human and agricultural background of Egypt in general and outlined the main descriptive characteristics of land-use change in the two study areas in particular as a basis for the analysis in Chapters 6-9. Agricultural policies were described both in terms of being drivers (Section 4.4.2) and responses (Section 4.5). This seeming contradiction will be discussed further in Chapter 11. Remote sensing images and questionnaire data were the two main sources of information used in the description. With regard to the remote sensing images, three key methods have been applied to determine changes in land-use and cover in the two study areas: visual interpretation, unsupervised classification and Normalised Difference Vegetation Index (NDVI). The main results indicated that crop patterns have experienced major changes in the two study areas with regards to the geographical distribution and crop area changes. In the Almansourah study area, key changes were the increase of cotton area and decrease in rice, maize and other crops. In contrast, the Alzaqazig study area has experienced an increase in cotton and rice area with minor increase in maize fields. These key changes will specifically focus on in Chapters 6-9. The results have also shown an increase in urban and rural urban settlements into agricultural land in the two study areas. Section 4.5, meanwhile, discussed changes in agricultural policies as a response of land-use change in the research region. Three key issues have been discussed in this section: irrigation policy in Egypt, development and changes in rice production in the Nile Delta and agricultural policies in the reclaimed land. The investigation in this section has used census data for rice area, production, yield and prices to determine the importance of changes in agricultural policies as a response affecting land-use change in the research region.

In the following chapter, the discussion will focus on the application of the DPSIR framework in understanding land-use change processes in the study areas. Multi-causality issue and explanation of the inter-relationships between different elements of the DPSIR framework will also be discussed in the next chapter.

Chapter 5: The DPSIR framework: application and results

5.1 Introduction

In Chapters 1 and 2 the history, development and applications of the DPSIR framework were presented. The way in which it can be used as an analytical framework for assessing land-use change and other human-environmental problems was also discussed. Chapter 3 outlined the practical application of the DPSIR framework in this thesis and the limitations and difficulties encountered for the measurement of the framework's indicators were described. This chapter will discuss and explain in more detail the way in which the DPSIR framework is able to provide a better understanding of land-use change processes in the research region as a basis for the analysis in Chapters 6-9. At the same time, the limitations due to the conceptualisation as a linear chain will be outlined (multi-causality). The application and explanation of the DPSIR's five components will be presented in Section 5.2. A discussion of the interrelationships between the DPSIR elements follows in Section 5.3 while the multi-causality issue with regard to the application of the DPSIR framework will be discussed in Section 5.4.

5.2 Applying the DPSIR framework in this study

This section will illustrate the practical application of the DPSIR framework in the explanation of land-use change to the two study areas in the eastern part of the Nile

Delta and explain the importance of the DPSIR's five components (driving forces, pressures, state, impacts and responses).

The methodological approach adopted in this thesis, as described in Chapter 3, is based on identifying, collecting and categorising different types of data associated with the two case study areas. The required data was collected through five diverse sources, as mentioned in Chapter3: remote sensing data, questionnaire data, participant observation, interviews and census data. The role of the DPSIR framework in this study is to organise, categorise and synthesise these data and information to produce a better understanding of land-use change processes in the two case study areas.

The DPSIR framework assumes that there is a chain of causal links in any system. It starts with *driving forces* which are represented by physical, economic as well as social and cultural drivers that exert *pressures* on land-use. The pressures influence the current land-use state and, as a consequence, the way in which land-use changes. State indicators give a description of the quantity and quality of physical, biological and chemical phenomenon in the area. This change leads to *impacts* on the economic performance that may bring about a societal *response*. However, the DPSIR framework is not entirely a linear causality type of model as there may be a series of different responses with regard to driving forces, pressures, state and impacts. The DPSIR framework, therefore, describes a dynamic situation, with attention for the various feedbacks in the system (Walmsley, 2002; Kristensen, 2004, Svarstad *et al.,* 2008).

The indicators used in the DPSIR framework characterise the main social environmental issues, such as climate change, globalisation, economic drivers, population growth, gender role, and land-use change in relation to the geographical levels at which these issues are investigated or at which they are managed. In designing indicators for each of these components at various geographical scales, the simplicity of the DPSIR framework is its key strength and the principles are very easy to communicate. However, it is important to stress that such a straightforward concept must be applied appropriately (Gabrielsen and Bosch, 2003).

The indicators for driving forces used in this study represent the physical, economic as well as social and cultural developments in the area under investigation as well as the corresponding changes in lifestyles. These indicators describe development expressed as the needs and activities of individuals (farmers), overall levels of consumption and production patterns related to agriculture and population growth (Gabrielsen and Bosch, 2003; Caeiro *et al.,* 2004). The present study has identified 11 indicators representing driving forces. These indicators are shown in Table 5.1.

Physical indicators	*Economic indicators*	*Social and cultural indicators*
1. The need for irrigation water *2.* Use of fertilisers *3.* Use of pesticides	*4.* Subsidies availability *5.* Private Banks loan availability *6.* Access to transport services *7.* Cost of transportation *8.* Current prices for crops	*9.* Population growth *10.* Farmers' educational levels *11.* Rural women's contribution in agriculture.

Table 5.1: Driving force indicators used in this study

Pressure indicators in the present study describe the use of resources and the use of land by human activities and environmental problems. The pressures exerted by society are transported and transformed in a variety of natural processes to show themselves as changes in land-use conditions. In this study, two pressure indicators have been identified: area affected by soil salinisation and area affected by desertification. Due to the pressure on land-use, the state of agricultural land changes. Three state indicators have been identified in this study: type of crops planted in the study areas, number of crops planted in one year and area of crops planted in the study areas. These changes then have impacts on the functions of land-use. An impact indicator in the present study is used to describe the expenditure related to reducing land degradation.

Response indicators refer to actions and responses by groups (and individuals) in society, as well as government attempts to prevent, compensate, improve or adapt to changes in driving forces, pressures, state of land-use or directly to impacts. Response indicators identified in this study are: irrigation system adopted, agricultural policies change, farmers receiving new skills and training, social policies, agricultural advice and settlement of new areas. Although the DPSIR framework can be viewed as a descriptive analysis with a specific focus on individual components in the physical, economic, social and cultural contexts, it is the interrelationships between the elements that introduce the dynamics into this framework and bring about changes. This issue is subject of the discussion presented next.

5.3 The interrelationships between the DPSIR elements

There has been general agreement amongst those using the DPSIR framework that the description of the causal chains from driving forces to pressures, state, impacts and responses is a very complex task (Gabrielsen and Bosch, 2003; Kristensen, 2004; Caeiro *et al.*, 2004; Pirrone *et al.*, 2005; Zhang and Fujiwara, 2007). As a result, experts tend to focus on specific elements and study the interrelationships between the DPSIR components using a series of sub-models. In this section, the discussion will focus on the three sub-domains and associated models included in the driving forces component of this study (see Chapter 3). These sub-domains are: the physical, economic as well as social and cultural sub-domain. Three sub-models will be presented to demonstrate the interrelationships between the various elements, although it should be stressed that all these drivers are interconnected.

5.3.1 Physical drivers

Physical drivers studied in this thesis are measured using three indicators: the need for irrigation water, use of fertilisers and use of pesticides. Irrigation procedures can be described in the context of a sub-DPSIR model as shown in Figure 5.1. Farmers' needs for irrigation water, their use of fertilizers and use of pesticides in farming production represent the physical driving forces which put pressure on agricultural production and land-use. The pressure resulting from high demand on water for agricultural purposes, use of fertilisers and pesticides will be reflected as shortage of irrigation water, reuse of irrigation water and soil and water pollution. These pressures will lead to changes in the current state of land-use (e.g. more cotton fields will replace rice area) which will, in turn, affect the health of crops, human health and soil quality. Such negative impacts require treatment or a solution.

Within this framework, the task of decision-makers is, therefore, that of analysing land-use changes and assessing the acting driving forces, their pressures, the consequences on current state, their ultimate impacts and eventually protecting the environment. From the assessment of impacts, decision-makers are required to determine appropriate responses in order to direct the final effect in the desired direction (a reduction in environmental harm). For example, there may be different responses to the various driving forces depending on the type of irrigation system being used. Long-term solutions are needed to replace the current method by a more efficient one (farmers' attitude and behaviour changes). Another response relates to agricultural advice policy

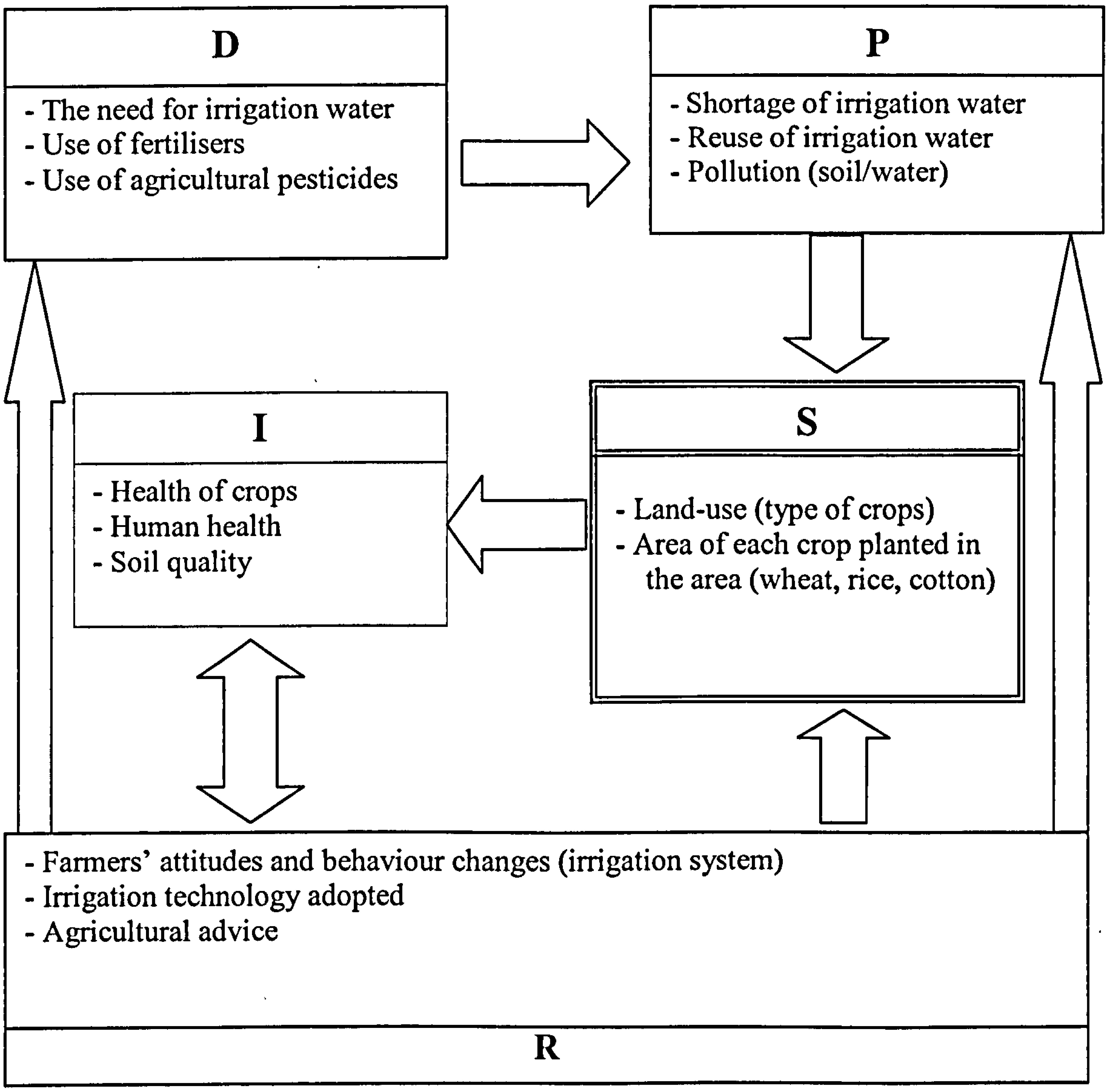


Figure 5.1: A conceptual DPSIR framework for physical drivers in the study areas
(Source: author; after Casazza *et al.*, 2002; Zalidis *et al.*, 2004, Koundouri *et al.*, 2006)

directed to farmers by raising their awareness about the importance of reducing the use of irrigation water. In the short-term, the government could tackle the shortage of irrigation water in some areas by securing additional water. Responses may also be directed to tackle impacts or current state problems by preventing soil degradation, for example, or by ensuring crops health.

5.3.2 *Economic drivers*

Economic drivers form the second sub-domain of the driving forces affecting land-use change in the two study areas (see Chapter 3). These drivers are measured using the following indicators: governmental subsidies availability, private bank loan availability, access to transport services and cost of transportation. In the context of the DPSIR framework (Figure 5.2), the need for capital (government subsidies and subsidies from private sources), the need for transportation means and the cost of these transportation means represent the economic driving forces that put pressure on land production and land-use. The pressures which farmers encounter in their agricultural production include financial hardship, lack of transportation means and higher costs of marketing. These pressures will affect the current state of crop and product market prices, the number of transportation means available for each farm and, ultimately, affect the living standard of farmers' families. As a result, there will be adverse effects on farmers and farming production. These impacts can be identified as shown in Figure 5.2 in the low quality of farm products, delay in farm product marketing, higher market prices for crops and other products and, in particular, low income for farmers' families. The responses will follow different directions. For example, long-term solutions to solve the problem could be directed to economic driving forces (governmental financial policy change or transportation policy change), or changes in farmers' attitude and behaviour (individual). Short term solutions are also possible responses in this case. They aim to improve the situation and can be directed towards pressure, state or impact components by facilitating procedures for loans or improving cooperative marketing.

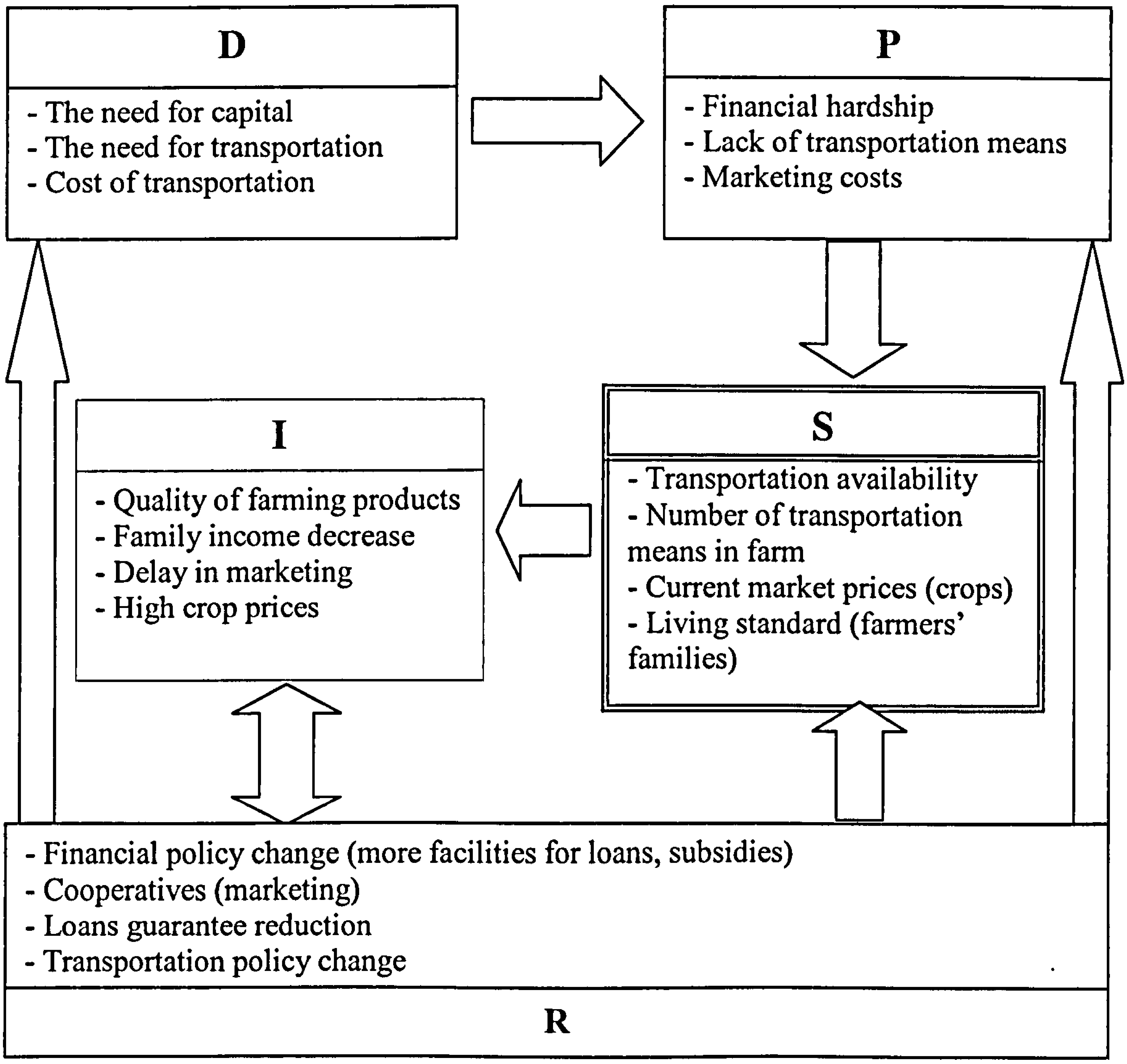


Figure 5.2: A conceptual DPSIR framework for economic drivers

(Source: author; after Casazza *et al.*, 2002; Zalidis *et al.*, 2004, Koundouri *et al.*, 2006)

5.3.3 Social and cultural drivers

Social and cultural drivers are the third sub-domain of driving forces affecting land-use change in this study. Three indicators have been identified to measure social and cultural drivers in the two study areas (see Chapter 3). These indicators are: population growth, farmers' educational levels and rural women's contribution in agriculture. The explanation of how these drivers are affecting land-use change in the two study areas in the context of the DPSIR framework, as shown in Figure 5.3, starts with the need for new houses and industrial land as a driving force which puts more pressure on agricultural land as a potential target for urban expansion. This driver is a particular issue in the Almansourah study area (see Chapter 4). Pressure on agricultural land will result in negative impacts such as reduction in the quantity and quality of crops, and will change the current state of land-use (increase in urban settlements and decrease in agricultural land). The responses by the government towards these driving forces,

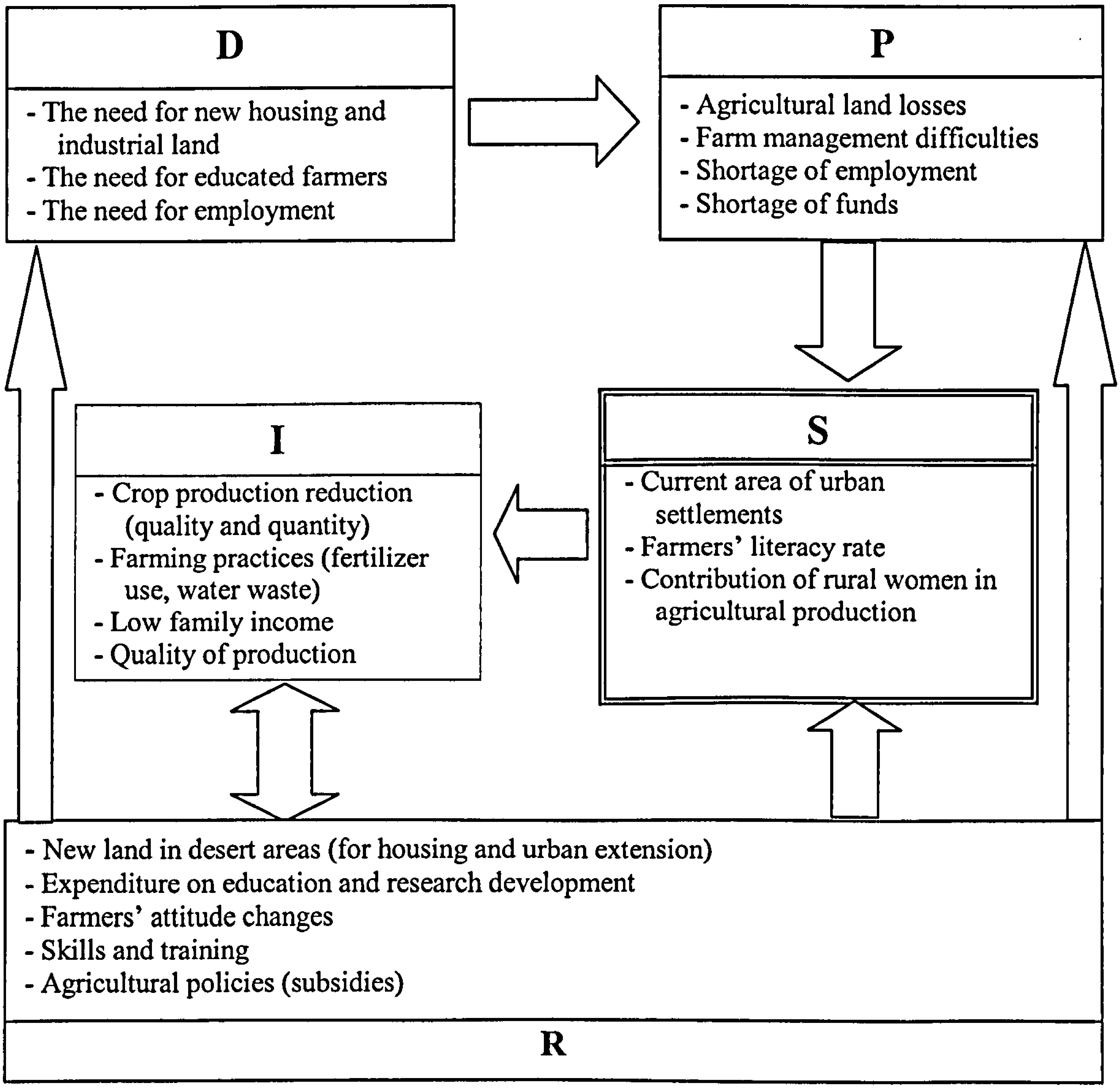


Figure 5.3: A conceptual DPSIR framework for social and cultural drivers

(Source: author; after Casazza *et al.*, 2002; Zalidis *et al.*, 2004, Koundouri *et al.*, 2006) pressure, impacts and the present state will vary from long-term responses to short-term reactions. For example, one of the long-term responses by the government in an attempt to confront soaring population growth is to facilitate family planning programmes. A short-term solution is supporting farmers to invest and live on the reclaimed land in desert areas and provide them with all facilities they need to reduce pressure from the old intensified agricultural land.

The above discussion has highlighted the importance of the interrelationships between the five components of the DPSIR framework and outlined the way in which all drivers that affect land-use change in the two study areas are interconnected. The negative impacts were often similar despite the very different physical, economic, social and cultural drivers. This explanation, therefore, suggests that there is a need for further investigation on the multi-causality issue in connection with the application of the DPSIR framework in this study. This argument is the subject of Section 5.4 and presented next.

5.4 Multi-causality issues and the application of the DPSIR framework

After having discussed the interrelationships and the dynamics in which the DPSIR elements are linked, this section will discuss the multi-causality issue in connection with the application of the DPSIR framework in this thesis. As an introduction to this section, the terms causality and multi-causality are defined before discussing them in the context of the DPSIR framework.

Causality describes a relationship between two variables in which the presence or absence of one variable (the cause) determines the presence or absence, or the value, of another variable (the effect). For a relationship to be *causal* three conditions must be met:

(1) A strong correlation must exist between the proposed *cause* and the *effect*;

(2) The proposed *cause* must occur before the *effect*;

(3) The cause must always be present when the effect occurs.

In some natural sciences, the assumption that a single *cause* brings about a single *effect* may be true. However, in social sciences, the relationships between *cause* and *effect* variables are much more complex and *multi-causality* better describes the relationships and explores human behaviour. Multi-causality recognizes therefore, that more than one variable can be the cause of an effect and complex hypotheses with two or more independent variables must be sought.

The existence of the interrelationships discussed in the previous section shows that the DPSIR framework, although often presented as a linear chain or a circle, can incorporate a very complex web of many interacting factors some of which may represent highly non-linear dynamics (Gabrielsen and Bosch, 2003; Pirrone *et al.*, 2005; Gheorghe and Stanners, 2006). Niemeijer (2002) goes as far as to suggest that the DPSIR framework "*hints at the causal position of each of the indicators in the causality chain, as it is often called, but fails to draw attention to the actual inter-linkages and causative patterns that relate one indicator to another*" (Niemeijer, 2002 cited in FAO, 2002: 22).

In the application of the DPSIR framework, the change in the state of land-use or impacts and consequences on society and individuals has several causes, some of which may be immediate and of local origin, others may be exerting their influence on a national or even international scale. Reductions in pressure indicators often result from a mixture of policy responses and changes in various driving forces. Examples of the multi-causality nature of the DPSIR framework implications in this study can be highlighted by focusing on the impacts of land-use in the three sub-models explained in Section 5.3. It is evident from Figures 5.1, 5.2 and 5.3 that changes in the state of land-use and the impacts resulting from these changes have *many* causes. For example, reduction in crop production (crops health, quality and quantity) and family income decrease could be due to changes in either physical, economic, social or cultural drivers. In addition, possible responses resulting from problems related to changes in land-use can be linked to one or more of the five components of the DPSIR framework. This also supports the notion that the DPSIR framework can include the theory of multi-causality.

5.5 Conclusions

The discussion and explanation presented in this chapter act as introduction to the results in Chapters 6-9 based on the application of the DPSIR framework used as a conceptual framework for this thesis. This chapter focused on three main issues associated with the DPSIR framework adopted in this study. Application of the DPSIR framework in this thesis has been presented first, then the interrelationships between the five components of the DPSIR framework have been explained and, the multi-causality issue associated with the implication of this study framework has been clarified in Section 5.4. Key points discussed in this chapter were: first, the different sub-domains of the possible driving forces (physical, economic and social and cultural) are all interconnected although they are discussed separately. A second key issue outlined in this chapter is the importance of the interrelationships between the DPSIR elements in understanding the causes and impacts of land-use change in the study areas. Lastly, the final section of this chapter highlighted the significance of the multi-causality concept in describing and analysing the relationships between relevant driving forces and land-use change in the two study areas. Chapters 6-9 will now discuss in more detail how the DPSIR framework can be used to understand land-use change in the two case study areas.

Chapter 6: Driving forces: results and discussion

6.1 Introduction

Chapter 4 outlined key descriptive characteristics (geographical, human and agricultural) of Egypt as a semi-arid country for this study and described the major land-use changes in the two study areas (Alzaqazig and Almansourah). The discussion in Chapter 5, meanwhile, focused on three key issues associated with the DPSIR framework adopted in this thesis. These issues are: application of this framework in the two case study areas, explanation of the interrelationships between the five components of the DPSIR framework and the multi-causality issue associated with the implication of the DPSIR framework in the two study areas. As stated in Chapter 1, one of the main aims of this study is to investigate the importance of the different components of the DPSIR framework (driving forces, pressures, state, impacts and responses) for explaining land-use change in the eastern part of the Nile Delta.

This chapter aims to discuss and analyse the most important driving forces that affect land-use changes in the two study areas. It tries to answer the question of "what are the most important driving forces that affect land-use change in the two study areas" based on the results obtained from remote sensing image analysis, questionnaire data, interviews with farmers and expert people from the two study areas, participant observation and census data (see Chapter 3). Questionnaire data will be analysed using the Statistical Package for the Social Sciences (SPSS) throughout this chapter and consequent chapters. This chapter also forms the basis for ranking the importance of driving forces and responses in affecting land-use change in the two study areas (Chapter 10).

The argument and the discussion in this chapter will be in the context of this study's DPSIR conceptual framework. The DPSIR framework has been adopted as the conceptual framework for the analysis to help improve the understanding of the complex linkages and feedbacks between the causes and effects of land-use change (see Chapter 5). The DPSIR framework also can identify the indicators that will explain and quantify these linkages and feedbacks (see Chapters 3 and 5; Ares, 2002 cited in FAO, 2002; Stocking, 2002 cited in FAO, 2002).

In order to achieve the aim mentioned above in determining the driving forces affecting land-use change over time and analyse the physical, economic, social and cultural factors (the need for irrigation water, subsidies, transportation availability and cost, population growth, farmers' educational level, etc) that affect land-use change in the eastern part of the Nile Delta of Egypt, this chapter is structured to analyse, discuss and evaluate each indicator as follows: Section 6.2 will discuss the physical drivers that affect land-use change in the two study areas. This includes a brief introduction about driving forces and then, the need for irrigation water will be discussed. In Section 6.3, economic drivers suggested to affect land-use change in the two study areas will be analysed and discussed (agricultural subsidies and transportation availability and cost). Section 6.4, meanwhile, will present an analysis and discussion of the social and cultural drivers affecting land-use change in the study areas. Social and cultural drivers assumed to affect land-use change in this study include population growth, farmers' educational levels and rural women's contribution in agriculture.

6.2 Physical drivers

6.2.1 Introduction

Driving forces in the context of this study's objectives are the human activities and influences that, when combined with environmental conditions, have an effect on environmental change (Turner II *et al.*, 1993; Pisano, 2002). As discussed in Chapter 5, indicators for driving forces describe the physical, economic, social and cultural developments in societies and the related changes in lifestyles, overall levels of consumption and production patterns (Bach, 2004). Three main sub-domains have been identified as the possible driving forces that affect land-use change in the two study area: physical, economic as well as social and cultural drivers (see Chapter 3).

Physical drivers play a vital role in land-use change and are important in determining farm management practices (MacDonald *et al.*, 2000; Bender *et al.*, 2005; Mottet *et al.*, 2006; Lambin and Geist, 2006). It is, therefore, of great importance to analyse comprehensively each component of physical drivers and identify the most important ones affecting land-use changes in the two study areas. Physical drivers included in this study consist of the following indicators: the need for irrigation water and fertilizer and pesticide use in the two study areas. The need for irrigation water will be discussed separately next, while fertilizer and pesticide use are going to be analysed and investigated in connection with other economic and social drivers in the context of this chapter.

6.2.2 The need for irrigation water

The main purpose of this section is to identify the importance of the need for irrigation water as one of the physical drivers in the study areas in terms of its contribution in explaining land-use changes occurring in the two study areas. To address this point, a general overview of the irrigation system in the study area is of great importance to begin with. Irrigation in the two study areas is very important as in other parts of Egypt and the reason is the absence of effective rainfall or groundwater except on the narrow band along the north coast (Moustafa, 2004) and Egypt's agriculture is almost totally dependent on irrigation.

Currently the irrigation procedures in Egypt are dependent on water released from the Nile by the Aswan High Dam (Hvidt, 1996). The construction of this dam allowed for the inter-year storage of water within Egypt to free the country from problems with upstream countries, and also allow irrigation authorities to release water systematically to respond to all downstream needs such as agricultural, industrial, household and tourism needs (Radwan, 1998). Water for agriculture is diverted from the main Nile River by a series of barrages into main canals, from these canals into secondary canals, and from them into other distribution canals from which the farmers draw water.

Farmers in the Delta draw water from 50 to 75 cm below the level of the fields so they must lift the water from the canals for their use (Water Communication Unit, MPWWR, 1996). The lifting technology and related procedures have always been a matter for the farmers rather than the government. Farmers are also charged with maintenance of the final canals but do not have direct control over the flow of water into it. The raising of water to field level is done through small, movable, diesel powered pumps and sometimes by using the scoop water wheel. Farmers usually share the lifting points and the field ditches and once the water is lifted it then flows through a network of ditches until it reaches the field where the irrigation is taking place. There may then be further networks of ditches inside the field, or the field may simply be flooded depending on the crop type. In order to have a closer look at the operation of local irrigation systems in the study areas, it is essential to analyse the institutional setting within which it operates as well as the cultural context within which farmers live and work (i.e. the formal and informal power structures which govern social behaviours).

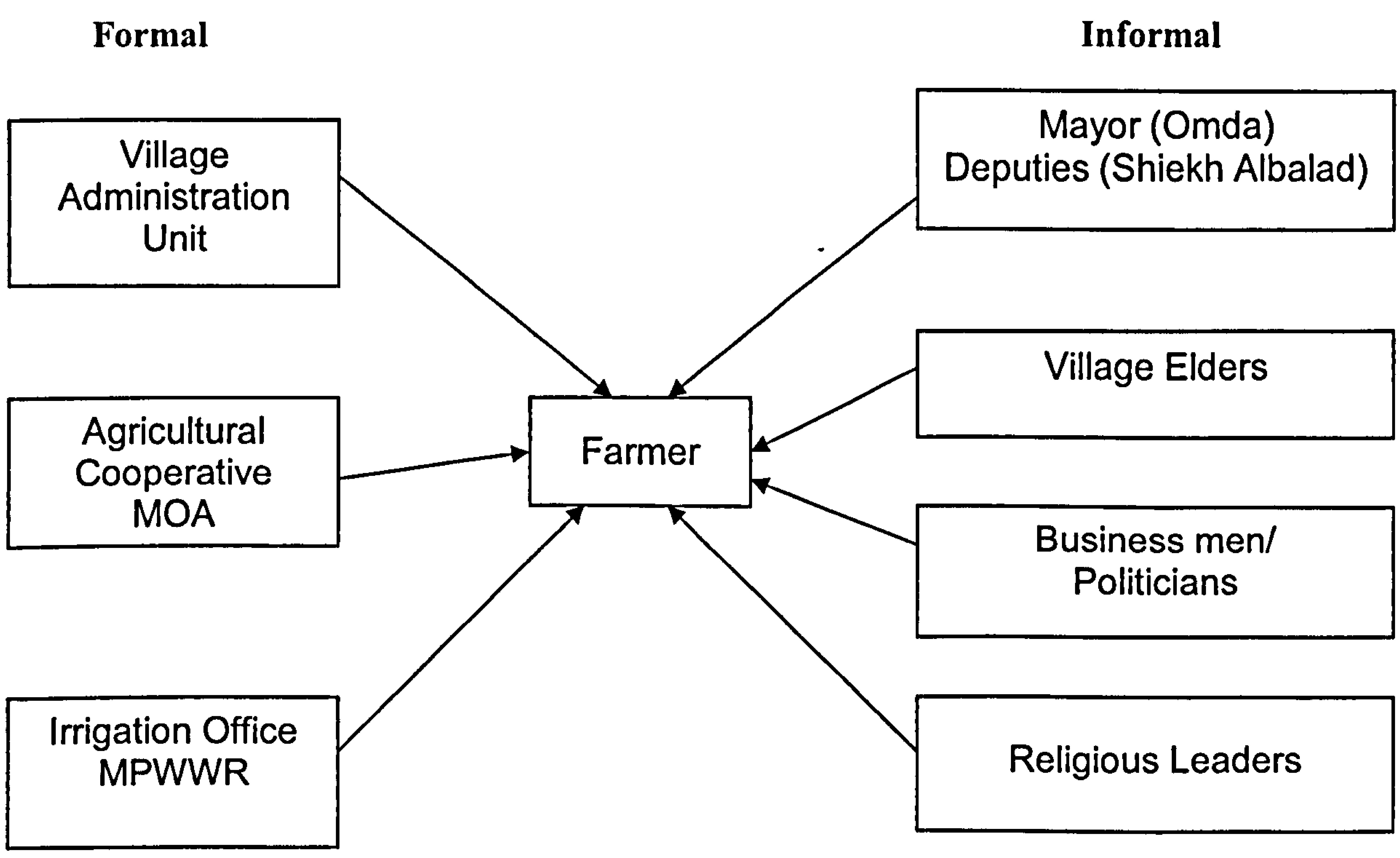


Figure 6.1: Formal and Informal institutions controlling irrigation systems in the Nile Delta (Source: Radwan, 1998)

As Figure 6.1 highlights, the principal formal institutions operating in rural communities are the village unit (council), the agricultural cooperative and the district irrigation office. However, only the last two play a significant role in irrigation organization. Responsibility for the operation of irrigation systems lies with the Department of Irrigation of Ministry of Public Works and Water Resources (MPWWR). This department's role is to control water flow down to the command area level below which supply is exercised on a rotational basis, either between whole command areas or between different parts of the larger command areas. Control over discharges below the main canal falls to the district engineer who is responsible for maintaining the rotations and discharges in the branch canal and secondary canal (Mesqa). However, farmer responsibility is limited to maintenance of his field ditches (Farmer respondent 12).

Usually the district engineer is in charge of clerks and water guards. The water guard (usually called Bahari by local farmers) is an employee of the MPWWR who is found at the village level and responsible for opening and closing the canals according to the rotations and noting upstream and downstream water level to ensure that water is reaching the fields at the end of the canal. In theory the water guard is required to visit all sections of the canal on a daily basis and should serve as a direct point between farmers and the MPWWR, but in reality, and in most locations, the water guard rarely visits farmers fields at the end of canals and measurements of water levels is not carried out on a regular basis (Radwan, 1997).

At the present time, irrigation water for agricultural use is free of charge for all farmers in the two study areas (Alzaqazig and Almansourah). However, the picture could change in the near future once a water crisis starts to emerge and farmers have to pay for using the Nile River water in their farm irrigation (Gouda, pers. comm., 2005; Farmer respondent 12). The results obtained from the questionnaire show that all farmers in both study areas are using the flooded (conventional) irrigation system on their farms and this method does not appear to have changed for a long time (Bowman and Rogan, 1999). Farmers' cooperation in cleaning and maintaining the canals is one of the common fundamental characteristics of farmers' behaviour in both study areas, and decision-making about what crops to grow is usually agreed between neighbours in order to ensure that everyone gets enough water. On the other hand, disputes occur among farm households over water. In an interview with a farmer from the Alzaqazig study area, the respondent stated that farmers are given an irrigation schedule by the Ministry of Public Work and Water Resources through the agricultural cooperative, and everyone knows his allocated time. However, as (Farmer respondent 12) also emphasised, disputes may occur when some farmers irrigate out of turn or borrow a pump and do not return it on time.

The main difference between Alzaqazig and Almansourah is the availability of irrigation water. Almansourah enjoys more water for irrigation due to its close location to the Domiat branch of Nile (Figure 3.1). The fundamental role that irrigation plays in agricultural production in both study areas makes this indicator one of the most important factors that affect land-use change (see Figures 4.19 – 4.22 in Chapter 4). At the same time, and because of the similarity between farmers' behaviour in using the irrigation system in the two study areas, it is of great importance to examine other indicators included in the physical drivers in the DPSIR framework to provide explanation of the changes occurring in land-use in both study areas. Fertilizer and pesticide use, as mentioned earlier in this chapter, will be investigated in connection with other economic, social and cultural drivers later in this chapter. However, analysis and discussion of economic drivers that affect land-use change in the two study areas are presented next.

6.3 Economic drivers

Based on the principles of economic theory, many land-use change researches have suggested that economic factors play a strong role in the decision making by land managers (e.g. input and output prices, subsidies, production and transportation costs, taxes, credit access) (Barbier, 1997; Dolman *et al.*, 2003; Lambin and Geist, 2006). Economic land-use change models, for example, begin from the viewpoint of individual landowners (farmers) who make land-use decisions with the objective to maximise expected returns or utility derived from farming and land-use, and use economic theory to guide model development including choice of functional form and explanatory variables (see Sections 2.4.5 and 2.4.8).

In the present study, key economic drivers included in the analysis are: agricultural subsidies and transportation availability and cost. In this part of the chapter, two groups of indicators will be analysed and investigated. Section 6.3.1 will investigate two indicators related to agricultural subsidies. The first one is the agricultural government subsidy and the second one is subsidies from private sources. In Section 6.3.2, the discussion on transportation will investigate two main economic indicators: transportation availability and transportation cost as a percentage of the total cost of agricultural production.

6.3.1 Agricultural Subsidies

The aim of this section is to investigate the contribution of government subsidies and subsidies from private sources in affecting land-use change in the two study areas. To facilitate achieving this aim, the following hypotheses will be presented at the outset:

- Null hypothesis one: there is no significant relationship between government subsidy and land-use change in both study areas.
- Null hypothesis two: there is no significant relationship between subsidies from private sources and land-use change in both study areas.

Before testing these hypotheses, it is crucial to highlight that the beneficiaries of the governmental credit service are all farmers, whether big or small landowners, or tenants. However, small farms (less than 2 ha) are predominant (67% of the cultivated areas and about 95% of the farmers at the national level; Saddik, 1995), and this study has confirmed that 75% of farmers in the Alzaqazig study area and 66.3% in the Almansourah study area have a farmland size of less than 2 ha (Table 6.1).

Study area	***Farmland size (ha)***				***Total***
	< 2 ha	***2 - 4 ha***	***4 - 8 ha***	***8 ha <***	
Alzaqazig	75 75%	22 22%	2 2%	1 1%	**100** **100%**
Almansourah	53 66.3%	17 21.3%	9 11.3%	1 1.3%	**80** **100%**
Total	128 71.1%	39 21.7%	11 6.1%	2 1.1%	**180** **100%**

Table 6.1: Farmland size in the two study areas

(Source: Author's questionnaire, 2006)

Given that the majority of farmers in both study areas have less than 2 ha farmland in extent, what does this result mean in terms of agricultural input subsidies? When the PBDAC was established, loans were mainly secured through existing possessions. However, because the majority of farmers in Egypt are smallholders, guarantees developed so that loans became the right of the holders, whether they were owners or tenants. Guarantees vary according to: the nature of the activity, size of the loan, and loan duration.

Generally, there is a diversity of approved guarantees for loans. The most important ones are: the cultivated land, the personal guarantee (for the rich), guarantees by institutions such as agricultural cooperatives, and "collective guarantees" (given to a group of individuals). However, the actual guarantee is the project itself, its economic feasibility, and the confidence in the owner's (the customer) ability to operate it successfully to get the expected return and thus repay the loan. Before investigating how the agricultural subsidy system (in cash or in kind) affects land-use change in the two study areas, it is worth illustrating all types of loans that the PBDAC is offering to farmers.

Short-term loans: providing short-term loans has been one of the main services of the PBDAC since its foundation. The loans are provided, in legal forms, to the farmers, aiming at promoting crop production and other agriculture-related activities and projects. Crop production loans provide an in-kind part of the inputs (seeds, fertilizers, pesticides, etc.). Additionally, they provide part of the cash funds necessary for some agricultural operations (agricultural labour, rental value, equipment, land preparation, harvesting, etc.). "In-kind" loans follow the technical ratios defined by the Ministry of Agriculture and depend on the availability of these inputs in the bank (Saddik, 1995). Cash loans depend mainly on cash credit limits and the money available in the bank, in addition to the extent of the bank's reassurance that loans will be repaid (Rashed, pers. comm., 2005). Terms of loan repayments differ according to the nature of the crop and the marketing system of the final product. Meanwhile, a part of the short-term loans is given to some agricultural projects in order to meet the running costs (for poultry and livestock production). Yet, the interest rate on short-term loans for such projects is not similar to crop credits. Generally, short-term loans do not exceed 14 months, and their due date is always connected with crop harvest and marketing by giving the project output (Goueli and El Miniawy, 1993).

Medium-term loans: These loans are provided to farmers whether individuals, groups, societies or companies to promote agricultural production or finance-related activities. They concern farm animals purchase, poultry farms, fodder factories, agro-industry projects, fish farm projects, agricultural machinery and equipment, the establishment of orchards and protected agriculture, the development of irrigation techniques, the improvement of marketing services, etc. The size of the loan depends on the nature of the activity, the farmer's financial status and his ability of self finance as well as on results of the technical and economic feasibility studies and the size and importance of the guarantees presented by the farmer. The duration of the medium-term loans ranges between 14 months and five years.

Long-term loans: The duration of such loans ranges between five and fifteen years. They provide loans for land reclamation projects and cultivation, construction of agricultural buildings and the establishment of orchards. In all cases, the due date of the loan should not exceed 75% of the expected life time of the assets which secure the loans (Mansour and Ghanima, 1997). This type usually includes a period of grace that varies in length according to the nature of the project and the timing of its first output. These loans are not provided unless there are adequate guarantees such as material assets.

Economic reform in the Egyptian agricultural sector was initiated in 1987 in the context of the Economic Reform and Structural Adjustment Programme (ERSAP). The measures taken included liberalization of pricing and marketing of major crops, eliminating subsidies on agricultural inputs, liberalizing input markets, eliminating interest rate subsidies on agricultural loans, and shifting from mandatory crop rotation to farmers' decision-based rotation. The second half of the 1990s witnessed liberalization of cotton marketing and trade and liberalization of the agricultural land rental market. Now, there are no government controls left in agriculture except the compulsory procurement of sugar cane at administered prices, the imposition of a maximum area for rice and geographical distribution for cotton types' cultivation at the district level (Siam, 1999).

In the context of this study's results, the statistical analysis in Tables 6.2 and 6.3 shows a significant relationship between government subsidy and farmland size in the two study areas (Alzaqazig $p=0.04$) and (Almansourah $p=0.001$). The difference in the significance level between the Alzaqazig study area and the Almansourah study area could be explained in the light of two facts. The first one is that farmers in Almansourah enjoy more comfortable financial standards and so could provide a guarantee for securing loans (see Chapter 3), and the other fact is that the percentage of farmers in the Alzaqazig study area who have farmland of less than 2 ha is larger than farmers in Almansourah (75% against 66.3%). Therefore, the difficulties they are facing in securing loans from the PBDAC would be greater due to the regulations and terms of the bank policy in securing guarantees.

Study area				***farmland size***		***Total***
				< 2 ha	***2 ha and over***	
Alzaqazig	***government subsidy***	Yes	Count	12	9	21
			%	57.1%	42.9%	100.0%
		No	Count	63	16	79
			%	79.7%	20.3%	100.0%
	Total		Count	75	25	100
			%	75.0%	25.0%	100.0%
Almansourah	***government subsidy***	Yes	Count	6	12	18
			%	33.3%	66.7%	100.0%
		No	Count	47	15	62
			%	75.8%	24.2%	100.0%
	Total		Count	53	27	80
			%	66.3%	33.8%	100.0%

Table 6.2: Farmland size and government subsidy in the two study areas

(Source: Author's questionnaire, 2006)

Study area	**Value**	**DF**	**Sig.**
Alzaqazig	**4.5**	**1**	**0.05^{+}**
Almansourah	**11.3**	**1**	**0.001***

($^{+}$ 95% significance level, * 99.9% significance level)

Table 6.3: Chi square test, government subsidy and farmland size in the two study areas

In order to look into the possible effects of government subsidies and subsidies from private sources on land-use changes in both study areas, a thorough examination of the nature of the relationships between agricultural government subsidies and subsidies from private sources and land-use change in the two study areas is of great importance. Table 6.4 shows percentages and numbers of farmers who were receiving government subsidies during the period 1984 and 2003 and Table 6.5 shows a chi square test in the two study areas to highlight the significance of the relationship between government subsidies and land-use change over the period 1984-2003.

Study area				***Land-use change***		***Total***
				No	Yes	
Alzaqazig	*government subsidies*	No	Count	29	47	76
			%	38.2%	61.8%	100.0%
		Yes	Count	6	18	24
			%	25.0%	75.0%	100.0%
	Total		Count	35	65	100
			%	35.0%	65.0%	100.0%
Almansourah	*government subsidies*	No	Count	45	17	62
			%	72.6%	27.4%	100.0%
		Yes	Count	13	5	18
			%	72.2%	27.8%	100.0%
	Total		Count	58	22	80
			%	72.5%	27.5%	100.0%

Table 6.4: Government subsidy and land-use change in the two study areas

(Source: Author's questionnaire, 2006)

Study area	**Value**	**DF**	**Sig.**
Alzaqazig	**1.4**	**1**	**0.2**
Almansourah	**0.001**	**1**	**1.0**

Table 6.5: Chi square test, government subsidy and land-use change

The analysis shown in Table 6.5 found that there is no significant association between government subsidies and land-use changes in either of the two study areas (Alzaqazig and Almansourah). In the meantime, the statistical analysis in Tables 6.6 and 6.7 shows the existence of a significant relationship between private source subsidies and land-use changes in the Alzaqazig study area ($p=0.04$) and no significant relationship between private source subsidies and land-use changes in the Almansourah study area ($p=0.2$). These results can be clarified in light of the Economic Reform and Structural Adjustment Programme (ERSAP) after 1992 when the government started to terminate the subsidy system and allowed the private sector to take over (especially for fertilizers subsidies) (see Chapter 4; Saad, 2002; Gouda, pers. comm., 2005). For example, in a survey by the Monitoring, Verification and Evaluation Unit (MVE) in 2001, farmers indicated that the best source for obtaining chemical fertilizer for the different field crops were private traders (33.4% - 51.9% of farmers) and agricultural cooperatives (33.6% - 51.2% of farmers), while only 0.7% - 1.4% of farmers preferred the Principal Bank for Development and Agricultural Credit (PBDAC). This means that the changes in the subsidies policy were against the preferences of the farmers (Saad, 2002). On the other hand, and because of the agriculture liberalization policy (see Chapter 4 for more detail) that the government has implemented, poor farmers especially in the Alzaqazig study area are most likely to look for new sources of agricultural subsidies through the private sector in an attempt to continue farming (switching to low cost crops for example or to another type of agricultural production such as livestock or poultry). However, if they failed with securing government subsidies required for agricultural production, there is the possibility that government subsidies alongside with other economic, social and cultural drivers are affecting land-use change in the two study areas (see multi-causality issues discussion in Chapter 5). As a result, there will be two different scenarios which farmers might follow. In the first one, farmers continue with their agricultural production under the new financial circumstances which means particular crops such as wheat or Egyptian clover are the most likely ones to be cultivated, as such crops do not require as much production costs and employment as the alternative crops rice or cotton. The second scenario is to look for alternative sources of subsidies such as private source subsidies and in this case, government subsidies are considered to be less important in affecting land-use change, and other possible drivers such as transportation availability and costs are likely to play a more important role in explaining changes in land-use in the two study areas.

Study area				***Land-use change***		***Total***
				No	Yes	
Alzaqazig	*private source subsidies*	No	Count	20	24	44
			%	45.5%	54.5%	100.0%
		Yes	Count	15	41	56
			%	26.8%	73.2%	100.0%
	Total		Count	35	65	100
			%	35.0%	65.0%	100.0%
Almansourah	*private source subsidies*	No	Count	34	16	50
			%	68.0%	32.0%	100.0%
		Yes	Count	24	6	30
			%	80.0%	20.0%	100.0%
	Total		Count	58	22	80
			%	72.5%	27.5%	100.0%

Table 6.6: Private source subsidies and land-use change in the two study areas

(Source: Author's questionnaire, 2006)

Study area	**Value**	**DF**	**Sig.**
Alzaqazig	**3.8**	**1**	**0.04***
Almansourah	**1.4**	**1**	**0.2**

*(*96% significance level)*

Table 6.7: Chi square test: private source subsidies and land-use change in the two study areas

The analysis and discussion in this section has highlighted the significant relationship between subsidies from private sources and land-use change in the Alzaqazig study area and discussed the possible explanation for this relationship. The analysis also suggested that government subsidies and land-use change have no significant association in both study areas. These results lead to further investigation of the relationship between land-use change and other possible economic drivers that affect changes in land-use in the two study areas. Analysis and discussion of the relationships between land-use change and transportation availability and cost are presented next.

6.3.2 Transportation availability and cost

Section 2.4.5 highlighted the widespread concern about the role that transportation plays in the agricultural and economic development of both developed and developing countries. The purpose of this section, therefore, is to draw attention to the importance of rural transportation for agricultural production and to examine the contribution of transportation availability and cost in determining land-use change in the two study areas. As an introduction to this section, two hypotheses associated with transportation availability and costs in the two study areas are presented first, and then link between these assumptions with other studies results are discussed next. The analysis and discussion of this study's data and information are then presented.

In order to achieve the main aim of this section, and based on the discussion presented in Section 2.4.5, the present study has the following hypotheses in relation to transportation availability and cost and land-use change in the two study areas:

- Null hypothesis one: there is no significant relationship between transportation availability and land-use change in the two study areas.
- Null hypothesis two: there is no significant relationship between transportation costs and land-use change in the two study areas.

Before testing these hypotheses, it is important to highlight some other study results and conclusions in association with these hypotheses (see Chapter 2 for more detail). A report by the World Bank (2006), which investigated the challenges for rural development in Upper Egypt, argued that the area faces important constraints in terms of market access, notably for perishable fresh products that are highly sensitive to transport conditions. It was estimated that up to 20 percent of the region's fruit products and 40 percent of its vegetable products spoil during transportation from the farm to the wholesaler. Estimates of tomatoes losses were as high as 60 percent (World Bank, 2006).

In Egypt 32% of the villages were connected to larger villages only by a network of footpaths. This figure is similar to that observed in other developing countries (e.g. in the Philippines less than 50% of the rural villages had access to the road system; in Bangladesh 80% of the villages have no direct access to a mechanised means of transport; in Indonesia 30.2% of the villages lacked proper road connection; and in Nigeria about 72% of rural settlements had no connection to any road. (Mijinyawa and Adetunji, 2005). While the government is only responsible for providing and maintaining the infrastructure required for transportation means operating at the national level, the private sector plays an important role in providing transportation services (52% between governorates) as well as governmental services (48% between governorates) (National Democratic Party Transport Policy, 2007). In the two study areas (Alzaqazig and Almansourah), farmers have access to railway services at city and main villages level. However, at local level, farmers have to decide whether to use their own transportation means such as handcarts, animal drawn carts, pickups or trucks to transport agricultural produce and inputs, or to use commercial and public ones. The decision depends on farm size and their financial situation.

In the context of the two study areas, the role of transportation availability and cost in affecting land-use change has been investigated by analysing the data obtained through the questionnaire using two types of questions. The first one was associated with the availability of farmers' own transportation in his/her farm (e.g. handcarts, animal drawn carts, pickups or trucks), and the second question was related to the cost of transportation as a percentage of the total agricultural production cost. Table 6.8 shows numbers and percentages of farmers in both study areas with availability of their own transportation means.

Study area		***Own transportation means availability***		***Total***
		Yes	No	
Alzaqazig	Count	33	67	100
	%	33%	67%	100.0%
Almansourah	Count	35	45	80
	%	43.8%	56.2%	100.0%
Total	Count	68	112	180
	%	37.8%	62.2%	100.0%

Table 6.8: Transportation availability in the two study areas

(Source: Author's questionnaire, 2006)

Table 6.8 shows that Almansourah has a higher proportion of farmers (43.8%) who confirmed that they possess their own transportation means such as handcarts, animal drawn carts, pickups or trucks, in comparison with Alzaqazig where only 33% of the farmers have their own transportation means. Unsurprisingly, these results reflect the earlier background mentioned in Chapter 3 regarding the higher standard of living and relative wealth that people and farmers enjoy in Almansourah compared with farmers in Alzaqazig, as well as better crop productivity and revenue in the old settled land where Almansourah is located. Table 6.9 shows transportation costs that farmers are deducting in the two study areas as a percentage of the total agricultural production cost in their farms.

Study area		*Transportation costs*		*Total*
		< 5%	*5 - 10%*	
Alzaqazig	Count	32	68	100
	%	32%	68%	100.0%
Almansourah	Count	23	57	80
	%	28.8%	71.2%	100.0%
Total	Count	55	125	180
	%	30.6%	69.4%	100.0%

Table 6.9: Transportation costs as % of total agricultural production costs in the two study areas (Source: Author's questionnaire, 2006)

In the two study areas and Egypt in general, apart from the high price of cars and other means of agricultural transport, petrol, taxes and insurance are cheap and the cost of running privately owned vehicles is only slightly more expensive than commercially and publicly rented ones. For these reasons, farmers in Alzaqazig are spending almost the same percentage of transportation cost (32% and 68%) in comparison with farmers in Almansourah (29% and 71%). But, to what extent does transportation availability affect land-use change in the two study areas? Investigating the nature of the relationship between the availability of transportation means and land-use pattern changes in the two study areas is, therefore, of great importance. Table 6.10 represents the distribution of farmers in both study areas in terms of the availability of transportation means (handcarts, animal drawn carts, pickups or trucks) and land-use change. Table 6.11 shows chi square test results for the relationship between transportation availability and land-use change in both study areas.

Study area				***Land-use change***		***Total***
				Yes	No	
Alzaqazig	***Transportation availability*** *(handcarts, animal drawn carts, pickups or trucks)*	Yes	Count	24	9	33
			%	72.7%	27.3%	100.0%
		No	Count	41	26	67
			%	61.2%	38.8%	100.0%
Total			Count	65	35	100
			%	65.0%	35.0%	100.0%
Almansourah	***Transportation availability*** *(handcarts, animal drawn carts, pickups or trucks)*	Yes	Count	15	20	22
			%	42.9%	57.1%	100.0%
		No	Count	7	38	58
			%	15.6%	84.4%	100.0%
Total			Count	22	58	80
			%	27.5%	72.5%	100.0%

Table 6.10: Transportation availability and land-use change in the two study areas

(Source: Author's questionnaire, 2006)

Study area	**Value**	**DF**	**Sig.**
Alzaqazig	**1.29**	**1**	**0.28**
Almansourah	**7.36**	**1**	**0.01***

(99% significance level)*

Table 6.11: Chi square test: transportation availability and land-use change in the two study areas

The significance test results in Table 6.11 show that land-use change has a significant relationship with transportation availability in Almansourah (p=0.01) and is not statistically significant in Alzaqazig (p=0.28). These results provide the evidence mentioned earlier in Chapter 3 that farmers in Almansourah enjoy better educational level and improved extension services and, most importantly, higher standards of living in comparison with farmers in Alzaqazig. Therefore, the importance of transportation availability in Almansourah has been greater as it could affect farmland productivity and profits, especially for farmers who deal with dairy products and perishable crops.

Table 6.12 shows the distribution of farmers in terms of transportation costs and land-use change in the two study areas. Table 6.13 shows Chi square test results for the relationship between transportation costs and land-use change in the two study areas.

study area				*Land-use change*		*Total*
				Yes	No	
Alzaqazig	*Transportation costs (% of total agricultural costs)*	< 5%	Count	20	12	32
			%	62.5%	37.5%	100.0%
		5-10%	Count	45	23	68
			%	66.2%	33.8%	100.0%
	Total		Count	65	35	100
			%	65.0%	35.0%	100.0%
Almansourah	*Transportation costs (% of total agricultural costs)*	< 5%	Count	13	10	23
			%	56.5%	43.5%	100.0%
		5-10%	Count	9	48	57
			%	15.8%	84.2%	100.0%
	Total		Count	22	58	80
			%	27.5%	72.5%	100.0%

Table 6.12: Transportation cost and land-use change in the two study areas

(Source: Author's questionnaire, 2006)

Study area	Value	DF	Sig.
Alzaqazig	0.129	1	0.72
Almansourah	13.64	1	0.00*

(100% significance level)*

Table 6.13: Chi square test: transportation costs and land-use change in the two study areas

According to the results obtained from these tables, transportation costs is a key driving force in Almansourah in affecting land-use change (p=0.00). On the other hand, this driver does not appear to play a vital role in land-use change explanation in Alzaqazig (p=0.44). Therefore, a further analysis is required to determine the importance of possible social and cultural drivers affecting land-use change in the two study areas. The analysis and discussion of this subject are presented next.

6.4 Social and cultural drivers

As stated in Chapter 4, rapid population growth in Egypt (about 1.9% annually) has resulted in considerable expansion of towns and cities with consequent loss of agricultural land in rural-urban areas. The problem is compounded because the majority of the country is so arid that the population density is high – 75 million people live on 4% of the total area (about 1 M km^2). Analysing and discussing social and cultural drivers affecting land-use change in the context of this study's framework (DPSIR) in both study areas is of great importance to achieve one of this study's objectives: "To investigate the importance of the different components of the DPSIR framework (driving forces, pressures, state, impacts and responses) for explaining land-use change in the eastern part of the Nile Delta". In this section, three main social and cultural drivers assumed to affect land-use change in the two study areas will be investigated:

population growth, farmers' educational levels and the contribution of rural women in agricultural production. However, before discussing these drivers it is important to investigate the role of farmers' ages and farm tenure in affecting land-use change in the study areas.

6.4.1 Farmers' ages

As discussed in Section 3.4.2, the questionnaire asked farmers their ages to see if there is a link between age and land-use change. The statistical analysis showed that the mean age in the Alzaqazig study area is 53.2 and in the Almansourah study area is 47.7. However, the age distributions are significantly different (p= 0.001). The age of farmers is normally distributed in Almansourah where it is skewed in Alzaqazig because there are relatively few young farmers (Figure 6.2).

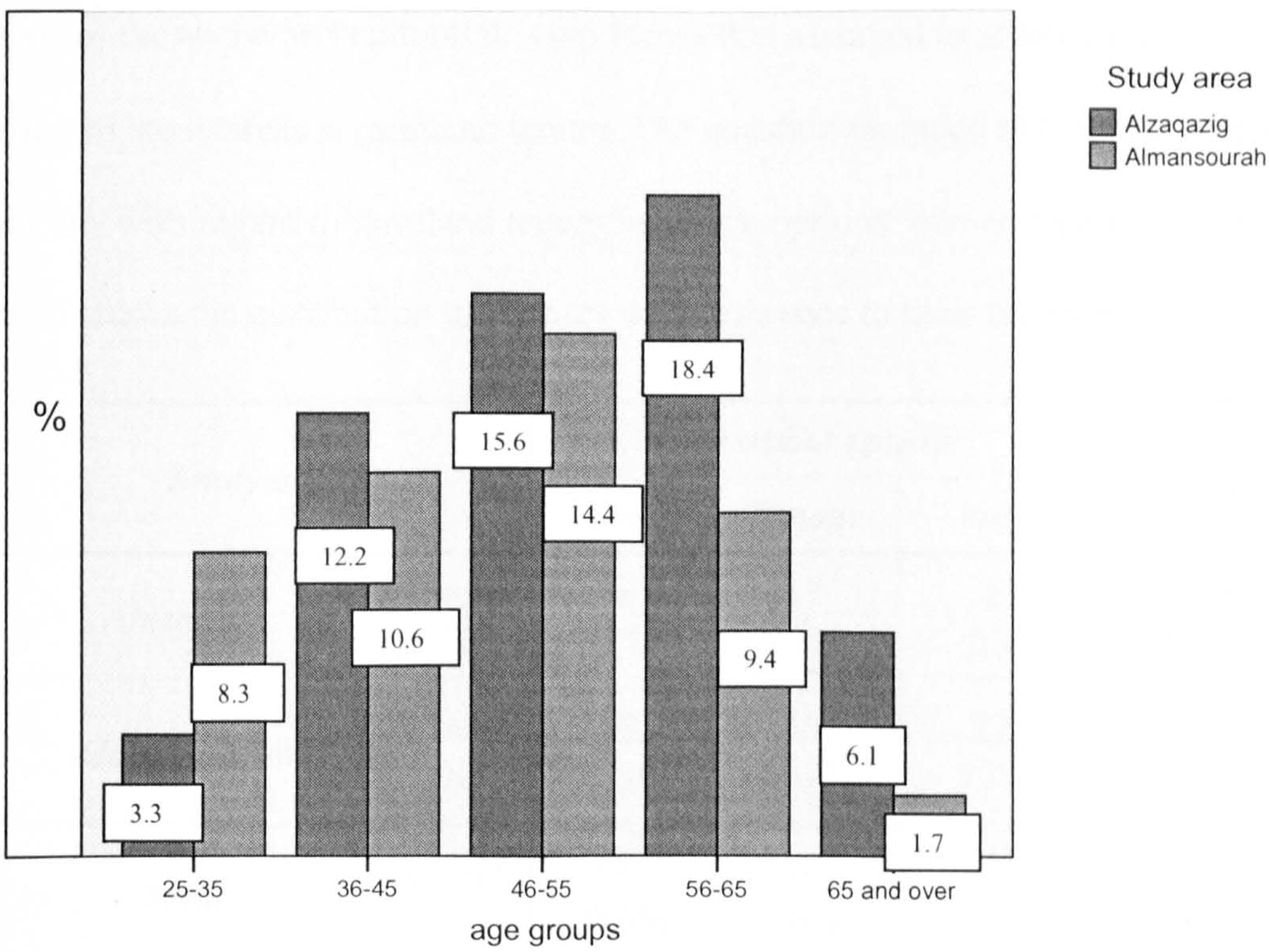


Figure 6.2: The distributions of farmers' ages in the two study areas

It is likely that farmers' age distribution in the Alzaqazig study area was not normally distributed because young men moved there in the late 1960s to early 1970s as the area was reclaimed. With regard to the role of farmers' ages in affecting land-use change in the two study areas, chi square test results in Table 6.14 show that there was no significant link between farmers' ages and land-use change in both areas (p= 0.3 in Alzaqazig and p= 0.2 in Almansourah).

Study area	**Value**	**DF**	**Sig.**
Alzaqazig	5.3	4	0.3
Almansourah	6.3	4	0.2

Table 6.14: Chi square test: farmers' ages and land-use change in the two study areas

6.4.2 Land tenure

One of the social and cultural driving forces that assumed to affect land-use change in the two study areas is farmland tenure. The question included in the questionnaire survey with regard to farmland tenure has three options: owner, tenant or both. Table 6.15 shows the distribution of farmers with reference to their farmland tenure.

Study area		*Farmland tenure*			*Total*
		owner	*Tenant*	*Both*	
Alzaqazig	Count %	78 78%	17 17%	5 5%	100 100.0%
Almansourah	Count %	49 61.3%	19 23.7%	12 15%	80 100.0%
Total	Count %	127 70.6%	36 20%	17 9.4%	180 100.0%

Table 6.15: farmland tenure in the two study areas

Table 6.15 shows that the majority of farmers in both study areas own their farmland; 78% of farmers in Alzaqazig own their farms compared to about 61% in Almansourah. Differences between the two locations reflect the different development histories of each area. In order to find out the role of land tenure in affecting land-use change in the two areas, a chi square test is required. Table 6.16 shows chi square test results for the two areas.

Study area	Value	DF	Sig.
Alzaqazig	1.2	2	0.5
Almansourah	2	2	0.4

Table 6.16: Chi square test, farmland tenure and land-use change in the two study areas.

It can be seen from Table 6.16 that land tenure has no significant association with land-use change in both study areas ($p=0.5$ in Alzaqazig and $p=0.4$ in Almansourah). There are, therefore, other social and cultural drivers that could affect changes in land-use in the two areas. The next section will examine the role of population growth as one the social and cultural derivers in affecting land-use change in the two study areas.

6.4.3 Population growth

The discussion presented in Chapter 4 regarding population growth as one of the possible drivers assumed to affect land-use change in the two study areas, has followed a descriptive methodology and used two types of data: remote sensing image data for the two areas between 1984 and 2003 (see Chapter 4) and population growth census data for the two study areas (Alzaqazig and Almansourah) during the period 1986-2006 (Figure 6.3)

In this section, however, analysis and explanation based on the results and discussion presented in Chapter 4 will be addressed. To do so, hypotheses can be raised here in terms of the differences between the two study areas, the rate of population growth in each of them, the greatest change in both, and the effect of population gr -

use change in the two areas. The main source which confirmed pressures on land are the satellite images that showed the encroachment of urban settlements (houses, industrial areas, commercial buildings and potential valuable bare land for future use) into agricultural land over time (1984 and 2003).

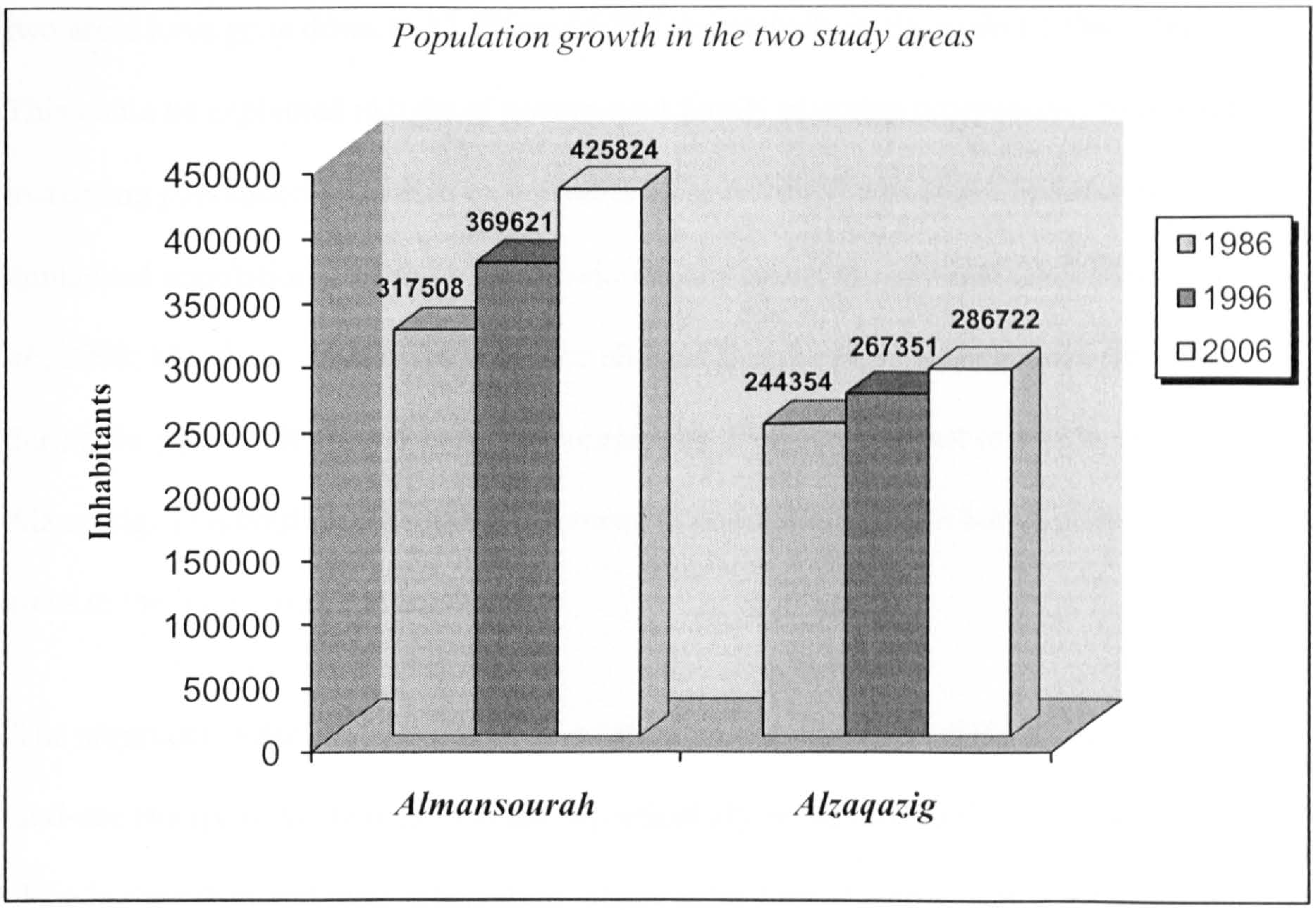


Figure 6.3: Population growth in Alzaqazig and Almansourah between 1986 and 2006. (Source: Brinkhoff, 2006)

An investigation of the satellite images has shown that there was an increase in area of urban settlements over time in the two study areas (1984-2003) (see Chapter 4).

Almansourah (as described before) has a big university and a good investment background, therefore is considered an attractive city for people to live and enjoy a high living standard (Chapter 3). On the other hand, Alzaqazig as a remote rural city situated adjacent to desert land, has poor living standards and limited investment opportunities (Chapter 3) so it is a considerably less attractive place to live. Following on from this, it is likely to see a much higher population growth rate in Almansourah, and for that reason more pressure on agriculture land is expected. Indeed, census data presented in Chapter 4 showed that population growth in Almansourah during the period 1986-1996 was 14.1% against 8.6% in Alzaqazig. However, both population growth rates in the two areas have gone down to 13.2% and 6.8% respectively in the period 1996-2006. This could be explained in light of government family planning programmes to control increasing population growth in recent years by revealing the negative impacts of unplanned population growth on the development plans at the national level (Khalifa *et al.*, 2000; Moreland, 2006). The data also showed that the population growth percentage during the period 1986-2006 in Almansourah was 25.4% in contrast to 14.8% in Alzaqazig. This confirms the great difference in population growth between the two areas in the long-term (20 years time).

The argument in the context of how population growth can make differences regarding land-use change in the two study areas is particularly related to the changes that take place in the urban and rural-urban areas. These areas form the prospective places where people react to any pressure which could affect their stability and, in this case, the population growth. In the Almansourah area, as the satellite images (Table 6.17; Figures 4.2 and 4.3 in Chapter 4) have shown, there has been an increase in urban and rural-urban settlements by 16% during the period 1984-1992. However, the encroachment of

Alzaqazig's urban and rural-urban areas into agricultural land during the same period was 22.1% (Table 6.17; Figures 4.4 and 4.5). This difference could be due to the availability of more free agricultural land in Alzaqazig in comparison with Almansourah at that time. On the other hand, and during the period 1992-2003, the rate of settlement increase in both areas Almansourah and Alzaqazig has gone down but in very different percentages. Urban and rural-urban encroachment rate into agricultural land was 14.4% in Almansourah against 2.9% in Alzaqazig. The reason for this discrepancy between both areas could be explained in light of the decline in population growth during this period as it decreased from 14.1% to 13.2% in Almansourah and from 8.6% to 6.8% in Alzaqazig. Conversely and as regards to the big difference between the two areas in the rate of change during the period 1992-2003, this could be justified for three reasons. Firstly, the emergence of new governmental policy towards agricultural investment and crop production; secondly, the growing awareness in farmers' minds about reclaimed land and the appearance of alternative land for extension and investment which will particularly apply to Alzaqazig due to its adjacent location to the desert land; and finally, the seriousness of the government to stop people from using valuable agricultural land for housing purposes.

The overall change rate during the period 1984-2003 can be seen in Table 6.17. There has been a 28.1% increase in the extent of urban and rural-urban areas in Almansourah and 24.4% in Alzaqazig. At the same time, population growth in Almansourah during the period 1986-2006 was 25.4% and 14.8% in Alzaqazig.

Year	Study area (ha)		% change		
	Alzaqazig	Almansourah	Years	Alzaqazig	Almansourah
1984	1365.48	1961.55	*1984-1992*	22.1%	16%
1992	1753.83	2335.77	*1992-2003*	2.9%	14.4%
2003	1806.12	2729.16	*1984-2003*	***24.4%***	***28.1%***

Table 6.17: Urban settlement change over 20 years (1984-2003) in the two study areas

(Source: ERDAS IMAGINE 8.7 images analysis)

These figures confirm that long-term land-use change in the urban and rural-urban settlements is related to population growth in these areas. In other words, there is a positive relationship between population growth rate and the rate of land-use change in urban and rural-urban areas (Figure 6.4).

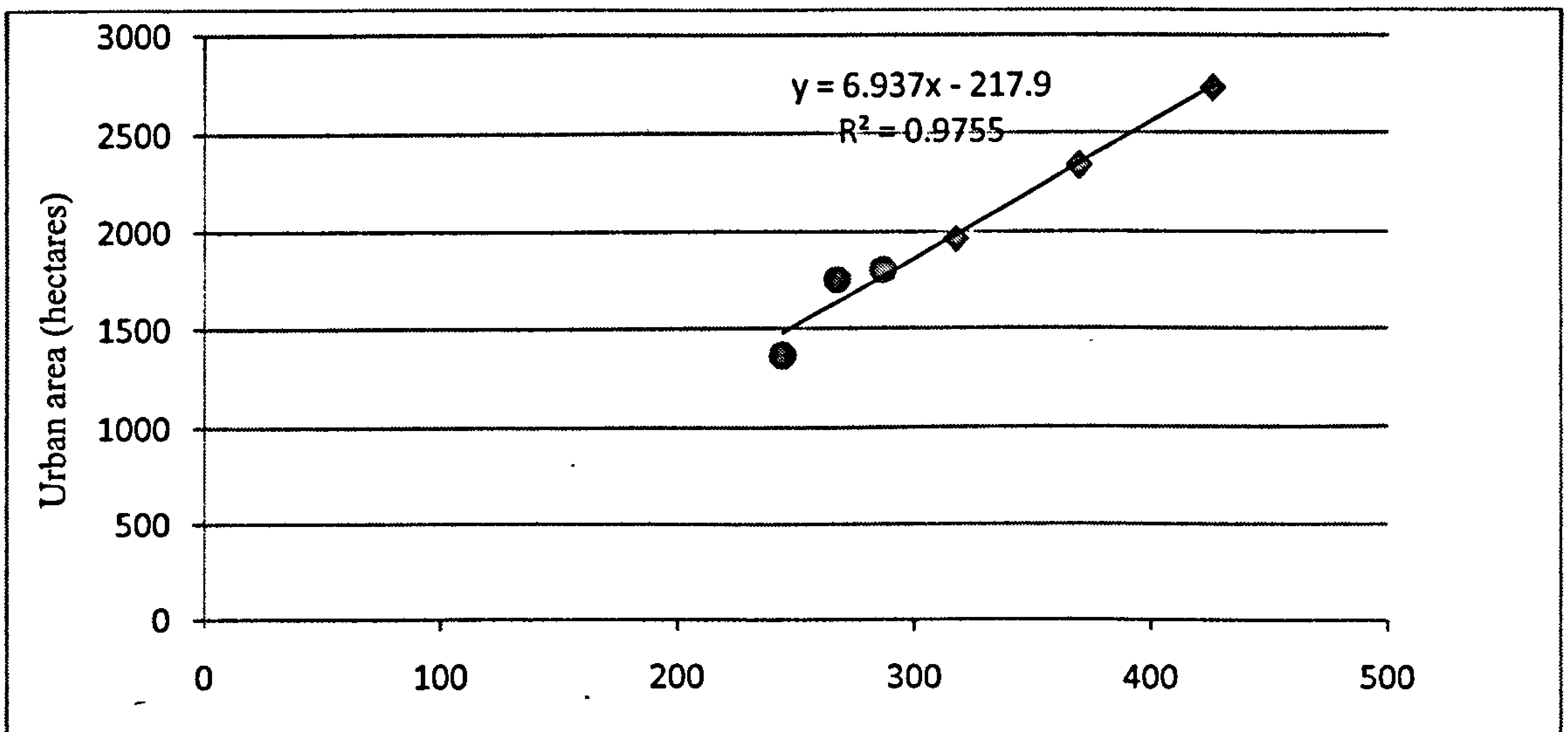


Figure 6.4: Relationship between population growth and urban area extension into agricultural land in the two study areas

(Source: Brinkhoff, 2006; Satellite image analysis)

Nevertheless, a further investigation in this context can be conducted to determine the greatest change in both study areas (Almansourah and Alzaqazig), to conclude if these expansions were planned or unplanned and finally, if they showed steady or disjointed growth.

Answers to these questions require a detailed investigation for each study area individually, although there are some common issues that are worth mentioning before starting to analyse each study location separately. In both study areas, in common with many other places, administrators may try to obtain personal benefits in return for panning approved (corruption). Therefore, when it comes to decide where to build new houses or any other facilities or services, these people could be influenced by others and an exchange of personal benefits to change the original location to another one (from desert land for example into agricultural land in order to raise the value of this land and surrounding areas dramatically). As a result, unplanned and disjointed change could result in the loss of good quality land, the most important and limited resource in agriculture and food production (Rashed, pers. comm., 2005).

In Almansourah where population growth was 25.4% during the last 20 years, people are looking at the adjacent agricultural fields as a potential place to expand and accommodate themselves because this is the only option they have. On the other hand, people in the Alzaqazig area, where the population growth was 14.8% during the last 20 years, have an alternative choice for their urban and rural-urban development due to the city location adjoining desert land. Depending on these differences between the two study areas, a possibility of the greatest changes that happened in Almansourah for the period 1984-2003 can be seen in Figures 4.2 and 4.3. It is clear that the increase in the urban and rural-urban area has occurred on the fringes and expanded into the crop fields. However, in Alzaqazig and in addition to the increase in the urban and rural-urban areas that occurred in the suburbs towards the agricultural land (see Figures 4.4

and 4.5), there has been another extension into new land at the border with the desert area due to the adjacent location of Alzaqazig to desert land. In summary, the rate of agricultural land lost in Almansourah because of the population growth during the period 1984-2003 was 1.5% every year. However, it was 1.3% annually in Alzaqazig during the same period 1984-2003. It is, therefore, mainly population growth that has affected land-use change in the two study areas, but clearly other drivers are also important. The next section will examine the role of farmers' educational levels in affecting land-use change and some farming practices in the two study areas.

6.4.4 Farmers' educational levels

As emphasised in Chapter 2, farmers' education plays an important role in agricultural production and affects land-use change (Damianos and Giannakopoulos, 2002; Mbonile, 2003; Bernetti *et al.*, 2006). Section 2.4.6 presented a broad discussion on the importance of both formal and informal education in farmers' decision-taking. The main aim of this section is to evaluate the role of farmers' educational levels in affecting farming practices, and to investigate the relationship between farmers' educational level and land-use change in the two study areas.

In the design of the questionnaire explained in the methodology chapter, two main questions were asked to obtain information about farmer's educational level and its role in determining changes in land-use. The first question aimed to obtain data about farmers' formal educational level, and the second aimed to obtain data about farmers' informal education. It is, therefore, important in the context of reviewing the current state of farmers' educational level and their possession of any informal education or training to define both formal and informal education. Formal educational level means the number of years spent at schools and colleges whereas informal education indicates any further education or training received by the farmer outside the official education institutes. Table 6.18 below shows figures and percentages of formal educational level and informal education and training for farmers in both study areas.

Study area		*Formal educational levels*					*Total*	*Informal education*		*Total*
		0 years	*1- 6 years*	*7-9 years*	*10-12 years*	*13 years and over*		*Yes*	*No*	
Alzaqazig	**Count**	30	32	2	14	22	100	27	73	100
	%	30%	32%	2%	14%	22%	100%	27%	73%	100%
Almansourah	**Count**	19	17	7	18	19	80	21	59	80
	%	23.7%	21.3%	8.8%	22.5%	23.7%	100%	26.3%	73.7%	100%
Total	**Count**	49	49	9	32	41	180	48	132	180
	%	27.2%	27.2%	5%	17.8	22.8%	100%	26.7%	73.3%	100%

Table 6.18: Formal and informal farmers' educational levels in the two study areas

(Source: Author's questionnaire, 2006)

Table 6.18 shows that almost one third of farmers in the Alzaqazig study area have no formal educational background whatsoever. In the Almansourah study area, meanwhile, almost a quarter of farmers confirmed they have no educational background. It is clear also that farmers in the Almansourah study area have higher formal educational levels than farmers in the Alzaqazig study area. The difference between farmers in the two areas in terms of the formal educational levels can be explained in the light of availability of educational facilities, and the existence of a big university in Almansourah (see Chapter 4).

In order to examine the relationship between farmers' educational levels and their farming practices, a comprehensive analysis for the data obtained through the questionnaire is of great importance, and evidence then could be available either to confirm or refute the hypothesis that well educated farmers are able to receive and adopt new innovations and technology in their farming system and have more ability to deal with their daily farming tasks such as communications with agricultural extension experts, using fertilizers and pesticides without any help from other family members and the ability for marketing and dealing with other associations.

Before examining the link between farmers' educational levels and farming practices, it is very important to review how often farmers follow the agricultural rotation recommended by the agricultural cooperatives in the two study areas. Table 6.19 shows the numbers and percentages of farmers in the two study areas with regard to agricultural rotation.

Study area		*agricultural rotation*			*Total*
		always	sometimes	never	
Alzaqazig	Count %	9 9.0%	53 53.0%	38 38.0%	100 100.0%
Almansourah	Count %	6 7.5%	48 60.0%	26 32.5%	80 100.0%
Total	Count %	15 8.3%	101 56.1%	64 35.6%	180 100.0%

Table 6.19: Farmers and agricultural rotation in the two study areas

(Source: Author's questionnaire, 2006)

The data shows that only a minority of farmers (9% in Alzaqazig and 7.5% in Almansourah) follow the agricultural rotation as recommended by the agricultural extension department. However, and as mentioned earlier, the critical issue in this context is to examine the relationship between farmers' educational level and whether they adhere to agricultural rotation in either Alzaqazig or Almansourah and the reasons, if any, for the difference. Table 6.20 below shows figures and percentages of farmers following agricultural rotation in the two study areas, while Table 6.21 shows the significance of the relationship between farmers' educational level and how often they follow the agricultural rotation.

Study area				*agricultural rotation* Yes	No	*Total*
Alzaqazig	*Formal educational level*	*illiteracy*	Count	17	13	30
			%	56.7%	43.3%	100.0%
		basic	Count	18	14	32
			%	56.3%	43.8%	100.0%
		average	Count	11	5	16
			%	68.8%	31.3%	100.0%
		advanced	Count	16	6	22
			%	72.7%	27.3%	100.0%
	Total		Count	62	38	100
			%	62.0%	38.0%	100.0%
Almansourah	*Formal educational level*	*illiteracy*	Count	14	5	19
			%	73.7%	26.3%	100.0%
		basic	Count	15	2	17
			%	88.2%	11.8%	100.0%
		average	Count	19	6	25
			%	76.0%	24.0%	100.0%
		advanced	Count	6	13	19
			%	31.6%	68.4%	100.0%
	Total		Count	54	26	80
			%	67.5%	32.5%	100.0%

Table 6.20: Farmers' educational level and agricultural rotation in the two study areas (Source: Author's questionnaire, 2006)

Study area	Value	DF	Sig.
Alzaqazig	2.2	3	0.5
Almansourah	15.7	3	0.001*

(99.99% significance level)*

Table 6.21: Chi square test, farmers' educational level and agricultural rotation in the two study areas

There is a significant relationship between farmers' educational level and the agricultural rotation in Almansourah ($p=0.001$) but not in Alzaqazig. The evidence confirms the assumption stated earlier that farmers with high levels of education have more ability to deal with their farming tasks. However, comprehensive explanations of how significant these results are will be presented after reviewing the link between farmers' educational level and other farming practices such as fertilizer use, pesticide use and manure recycling, and other social factors like family role in agricultural production.

To find out the nature of the relationship between farmers' educational level and their use of fertilizers in both study areas, a statistical analysis of the data is needed. Table 6.22 below shows numbers and percentages of farmers in the two study areas with

Study area				*Fertilizer use*		*Total*
				Yes	No	
Alzaqazig	*Formal educational level*	*illiteracy*	Count	24	6	30
			%	80.0%	20.0%	100.0%
		basic	Count	25	7	32
			%	78.1%	21.9%	100.0%
		average	Count	11	5	16
			%	68.8%	31.3%	100.0%
		advanced	Count	16	6	22
			%	72.7%	27.3%	100.0%
	Total		Count	76	24	100
			%	76.0%	24.0%	100.0%
Almansourah	*Formal educational level*	*illiteracy*	Count	14	5	19
			%	73.7%	26.3%	100.0%
		basic	Count	12	5	17
			%	70.6%	29.4%	100.0%
		average	Count	19	6	25
			%	76.0%	24.0%	100.0%
		advanced	Count	14	5	19
			%	73.7%	26.3%	100.0%
	Total		Count	59	21	80
			%	73.8%	26.3%	100.0%

Table 6.22: Farmers' educational level and their use of fertilizers in the two study areas (Source: Author's questionnaire, 2006)

regard to their use of fertilizers in crop production, and Table 6.23 shows the significance of this relationship.

Study area	Value	DF	Sig.
Alzaqazig	0.93	3	0.81
Almansourah	0.15	3	0.98

Table 6.23: Chi square test, farmers' educational level and fertilizer use in the two study areas

There is no significant relationship between farmers' educational levels and their use of fertilizers in either study area (p=0.81 in Alzaqazig and p=0.98 in Almansourah). This result can be explained partly by the practice of using manure (see later) and because this may be the responsibility of women (see Section 6.4.5). The relationship between farmers' educational levels and pesticide use is shown in Table 6.24 below and is also

Study area				*pesticide use* Yes	*pesticide use* No	*Total*
Alzaqazig	*Formal educational level*	*illiteracy*	Count	23	7	30
			%	76.7%	23.3%	100.0%
		basic	Count	26	6	32
			%	81.3%	18.8%	100.0%
		average	Count	11	5	16
			%	68.8%	31.3%	100.0%
		advanced	Count	17	5	22
			%	77.3%	22.7%	100.0%
	Total		Count	77	23	100
			%	77.0%	23.0%	100.0%
Almansourah	*Formal educational level*	*illiteracy*	Count	13	6	19
			%	68.4%	31.6%	100.0%
		basic	Count	12	5	17
			%	70.6%	29.4%	100.0%
		average	Count	19	6	25
			%	76.0%	24.0%	100.0%
		advanced	Count	14	5	19
			%	73.7%	26.3%	100.0%
	Total		Count	58	22	80
			%	72.5%	27.5%	100.0%

Table 6.24: Farmers' educational level and pesticide use in the two study areas

(Source: Author's questionnaire, 2006)

not significant in either Alzaqazig (p=0.82) or Almansourah (p=0.95) (Table 6.25).

Study area	**Value**	**DF**	**Sig.**
Alzaqazig	**0.94**	**3**	**0.82**
Almansourah	**0.36**	**3**	**0.95**

Table 6.25: Chi square test, farmers' educational level and pesticide use the two study areas

Table 6.26 shows numbers and percentages of farmers regarding their formal educational levels and the role of their families in farming practices in the two study areas. Table 6.27 shows the significance of the relationship between farmers' educational levels and their families' role in farming practices.

Study area				*Family role in agricultural production*: *they participate*	*they do not*	*Total*
Alzaqazig	*Formal educational level*	*illiteracy*	Count	25	5	30
			%	83.3%	16.7%	100.0%
		basic	Count	25	7	32
			%	78.1%	21.9%	100.0%
		average	Count	10	6	16
			%	62.5%	37.5%	100.0%
		advanced	Count	7	15	22
			%	31.8%	68.2%	100.0%
	Total		Count	67	33	100
			%	67.0%	33.0%	100.0%
Almansourah	*Formal educational level*	*illiteracy*	Count	11	8	19
			%	57.9%	42.1%	100.0%
		basic	Count	11	6	17
			%	64.7%	35.3%	100.0%
		average	Count	8	17	25
			%	32.0%	68.0%	100.0%
		advanced	Count	10	9	19
			%	52.6%	47.4%	100.0%
	Total		Count	40	40	80
			%	50.0%	50.0%	100.0%

Table 6.26: Farmers' educational level and family role in agricultural production in the two study areas (Source: Author's questionnaire, 2006)

Study area	**Value**	**DF**	**Sig.**
Alzaqazig	**17.9**	**3**	**0.00***
Almansourah	**5.2**	**3**	**0.15**

*(*100% significance level)*

Table 6.27: Chi square test, farmers' educational level and family role in agricultural production in the two study areas

Table 6.28 shows numbers and percentages of farmers regarding their formal educational levels and manure recycling in the two study areas. Table 6.29 shows the significance of the relationship between farmers' educational levels and manure recycling.

Study area				*Manure recycling* Nile or canal	*Manure recycling* in the soil	*Total*
Alzaqazig	*Formal educational level*	*illiteracy*	Count	18	12	30
			%	60.0%	40.0%	100.0%
		basic	Count	14	18	32
			%	43.8%	56.3%	100.0%
		average	Count	6	10	16
			%	37.5%	62.5%	100.0%
		advanced	Count	8	14	22
			%	36.4%	63.6%	100.0%
	Total		Count	46	54	100
			%	46.0%	54.0%	100.0%
Almansourah	*Formal educational level*	*illiteracy*	Count	13	6	19
			%	68.4%	31.6%	100.0%
		basic	Count	7	10	17
			%	41.2%	58.8%	100.0%
		average	Count	7	18	25
			%	28.0%	72.0%	100.0%
		advanced	Count	7	12	19
			%	36.8%	63.2%	100.0%
	Total		Count	34	46	80
			%	42.5%	57.5%	100.0%

Table 6.28: Farmers' educational level and manure recycling in the two study areas

(Source: Author's questionnaire, 2006)

Study area	Value	DF	Sig.
Alzaqazig	3.7	3	0.3
Almansourah	7.6	3	0.05*

(95% significance level)*

Table 6.29: Chi square test, farmers' educational level and manure recycling

Figures and percentages from Tables 6.26 and 6.27 above show a very significant relationship between farmers' educational levels and family role in farming practices in the Alzaqazig study area (p=0.00). However, this relationship was not significant in Almansourah (p=0.15). Tables 6.28 and 6.29 also show that farmers' educational levels have affected significantly the way that farmers deal with manure recycling in Almansourah (p=0.05) but that it has not had any significant influence in manure recycling in the Alzaqazig study area (p=0.3). So, how significant are these relationships and how can they be explained?

It is important to mention that as farmers' educational level goes up, the ability to access information increases. For example, farmers suffering from financial problems may be more aware of them and try to solve them by seeking to secure loans or finance support in order to get hold of agricultural input required for their farming production. As a result of these farming practices, crop and livestock husbandry improved and that means more income is generated. The additional profit then can be used to develop the current status of farmers' educational levels and once again the cycle repeats itself, and any improvement in farmers' educational levels will be reflected as greater productivity and more income is going to be gained.

As this study' framework assumed, that there is no single driver affects land-use change independently (multi-causality), the next section will examine rural women's contribution to agricultural production and land-use change as one of several social and cultural drivers assumed to affect land-use change in the two study areas.

6.4.5 Rural women and their contribution in agriculture

As Chapter 2 highlighted, previous studies have suggested that rural women often have an important role in agricultural production and farming practices (Rahman, 2003; Damisa and Yohanna, 2007). This section, therefore, examines the importance of rural women's contribution in agricultural production and land-use change in the two study areas. In order to achieve this aim, the relationship will be investigated between rural women's role and farming practices in the two study areas (Alzaqazig and Almansourah).

Many studies have suggested that rural women participate little in decision-making at the household level in irrigated areas (FAO, 1995; Alozabie, 1997; Ahmed, 1999; Echtaie, 2001). It is generally assumed that men have almost exclusive authority on matters related to seeds, buying and selling of livestock and land, use of fertilizers, pesticides and agricultural machinery, what to grow and where to sell produce. Conversely women tend to make decisions on poultry and contribute to decisions on agriculture projects and the vaccination of livestock.

According to official statistics (FAO, 1995), only about 4% of those economically active in agriculture in 1986 in Egypt were women, and this rose to about 10% when unpaid family labour was included. However, statistics often do not reflect the true contribution of women to agriculture because these statistics exclude women's subsistence production and domestic work. In interviews with farmers from Alzaqazig and Almansourah, it was noted that the division of agricultural labour between men and women in the Nile Delta varies by crop. Overall, men carry out most of the land preparation, planting, weeding, irrigation and pest control. Women contribute moderately to seed preparation, applying fertilizers and harvesting, and significantly to storage and marketing (farmer respondent 12, 21, 112). Food processing is the primary responsibility of women. In animal husbandry, men are primarily responsible for the care of water buffalo, donkeys, cows and sheep, while women carry out most of the milking, processing and marketing of milk and animal products. Women also carry out virtually all domestic tasks, including water and fuel collection, and food processing and preparation.

The contribution of woman in the labour force at the national level in Egypt is low (15.4%) as is their enrolment rate in education, especially at the university level where it is only 29.4%. and their unemployment rate is 19.8% of the labour force (Egypt Human Development Report, 2003). During recent years, women's status has progressed a lot. Female literacy has improved, and so has school enrolment for girls and women participation in the workforce, but significant inequalities still exist (UNDP Egypt Human Development Database, 2003)

It has been stated by many researchers and studies that rural women play a vital role in food and agricultural production in Egypt and other developing countries (Ghorayshi and Belanger, 1996; Kazim, 1997; Azoz, 1998; Echtaie, 2001; Robinson, 2004). In this study, the most important question is how rural women's contribution in farming practices affects land-use changes? How significant are the differences between the two study areas in terms of family and women's contribution?

It has been noted during the data collection period that there was not a single woman in charge of the farm or decision making, although the Egyptian national report for combating desertification mentioned that a fifth of households in Egypt are headed by women. The reasons for the latter are divorce, death of the husband, international migration and family instability (Hegazi *et al.*, 2005). The importance of rural women's role in agricultural production in the two study areas comes from their contribution in farming practices and activities such as seed preparation, applying fertilizers, pesticide use and other activities, although this participation does not become visible in the official statistics and the agricultural annual census (Tables 6.30 and 6.31).

Study Area		***Women's contribution to agricultural production***		***Total***
		They contribute	They do not contribute	
Alzaqazig	Count	47	53	100
	%	47%	53%	100%
Almansourah	Count	12	68	80
	%	15%	85%	100%
Total	Count	59	121	180
	%	32.8%	67.2%	100%

Table 6.30: Women's role in agricultural production in the two study areas

(Source: Author's questionnaire, 2006)

Study area		*Family contribution to agricultural production*		*Total*
		They contribute	*They do not contribute*	
Alzaqazig	Count	72	28	100
	%	72%	28%	100%
Almansourah	Count	40	40	80
	%	50%	50%	100%
Total	Count	112	68	180
	%	62.2%	37.8%	100%

Table 6.31: Family contribution to agricultural production in the two study areas

(Source: Author's questionnaire, 2006)

Based on this study's results (Table 6.30), there is a significant difference between women's contribution to agricultural production in both study areas. The figures from Table 6.31 above show that rural families in Alzaqazig are contributing to agricultural production at a very high percentage, in comparison with rural families from Almansourah (72% against 50%). Chi square tests confirmed the significant differences in women's contribution in decision-taking regarding land-use change between both study areas. The relationship between family role and land-use change was significant in Alzaqazig (p=0.063) and not significant in Almansourah (p=0.45) (see Table 6.32).

Study area	**Value**	**DF**	**Sig.**
Alzaqazig	**3.85**	**1**	**0.06***
Almansourah	**1**	**1**	**0.45**

(94% significance level)*

Table 6.32: Chi-square test, family role in agricultural production and land-use change in the two study areas

Although women in both areas are facing difficulties and constraints in terms of their involvement in farming practice (e.g. late night irrigation), the dominance of family farming systems in the Nile Delta and in Alzaqazig particularly makes women's role very important and inevitable.

Thirteen farmers in the Alzaqazig study area (13%; Farmer respondent 12, 16, 21, 22, 29, 34, 36, 42, 45, 49, 62, 67, 95) confirmed that the age of their daughters that helped in agricultural production was between 8 and 15 years old. On the other hand, none of Almansourah's farmers stated that there is a contribution of any girl under the age of sixteen. These facts could be confirmed from the figures obtained from the Egyptian Human Development Report (2003) for the region of Sharkia and Dakahlia where the two study areas are located. (Sharkia is the county where the Alzaqazig study area is located and Dakahlia is the county where the Almansourah study area is located; Table 6.33).

Governorate	***Basic Education (enrolment ratios)***				***Females 15+ with secondary or higher education %***	***Women in Labour force (as % of total***
	Total	***Primary***	***Preparatory***	***Secondary***		
El-Sharkia[1] ***(Alzaqazig)***	**93.7**	**96.9**	**88.5**	**52.5**	**21.1**	**13.4**
El-Dakahlia[2] ***(Almansourah)***	**98.6**	**99.1**	**97.4**	**59.2**	**25.5**	**18.3**

Table 6.33: Women status: Education and Labour, Human Development Report, 2003 (Source: UNDP and INP, Egypt Human Development Report, 2003).

[1] El-Sharkia is the county where the Alzaqazig study area is located.
[2] El-Dakahlia is the county where the Almansourah study area is located.

So what do we understand from these figures and facts about rural women's educational levels and their participation in agricultural production? And how do rural women withdrawn from farming labour affect agricultural production and land-use change? Before answering these questions, it is worth discussing the most important social and economic issues related to rural women in the Nile Delta and Egypt in general.

Rural women suffer from lack of ownership of agricultural resources and not one woman was a farm owner out of the 180 farm holds involved in this study (see also the National Report for Combating Desertification, 2004). Therefore, rural women do not participate in decision-making processes. They also suffer from the lack of technology in the performance of their agricultural tasks. They have minimum income and therefore they suffer from high poverty levels. Rural women also suffer from high illiteracy between 52.9% and 63% in some rural areas of Egypt (Echtaie, 2001; Hegazi *et al.*, 2005).

It has been shown that the contribution of rural women in agricultural production and farming practices in the Alzaqazig study area is more significant than the Almansourah study area. This can be explained partly in terms of the women's educational levels and poverty of the area. There is a general tendency in Egypt for both boys and girls to leave school at a younger age in poor areas to support their families financially. There is less need to pay for labour when women and children work on the family farm. All indicators (Egypt Human Development Database, UNDP, 2003) have shown that Almansourah has higher percentages of women with higher educational levels (see Table 6.33) and fewer women in the agricultural labour force in comparison with Alzaqazig (see Table 6.33). As a result, one outcome is that the educational level of women in Almansourah will rise because the need to leave school early has been removed. The second outcome is related to the economic level of the family. There are several ways in which farmers can respond to the loss of free employment or the extra cost of outer employment. One is to change to a more profitable crop. Another possibility is to look for an alternative crop type which needs less employment (Egyptian clover instead of wheat because Egyptian clover does not need high care like wheat for example, or rice instead of cotton because rice needs less employment than cotton). This explanation was supported by interviewing farmers in the Alzaqazig study area. They confirmed that one of the reasons for choosing wheat in winter and cotton in summer is the availability of family employment, particularly females. A farmer from Alzaqazig emphasised this (Farmer respondent 12):

> *"I am saving a good amount of money because of the help I receive from my wife and daughters in farming activities, especially when I cultivate cotton as it needs much work and care".*

In an interview with another farmer in the Alzaqazig study area (Farmer respondent 95), he confirmed that:

> *"it is important to save some money by employing all members of the family including females instead of paying outside workers. This is particularly true when choosing to cultivate wheat in winter and cotton in summer".*

As a result, land-use in Alzaqazig is limited to some extent by the role of rural women in farming practices and agricultural production. Conversely, land-use in Almansourah is less likely to be limited by women's contribution in agricultural production.

Moving to another crucial issue associated with the relationship between the contribution of women in agricultural production and the educational level of farmers in the two study areas, the statistical analysis revealed in Table 6.34 shows data for each group and Table 6.35 shows the significance of this relationship. To explain why rural women are contributing more significantly in the Alzaqazig study area than in the

Almansourah study area, it is essential to investigate the relationship between farmers' educational level (who are in charge of the farm) and women's participation in agricultural production (female family members). It appears from the figures and percentages in Tables 6.34 and 6.35 that women's role in agricultural production is vital in the farms headed by "illiterate" or "low educational level" farmers. This can be explained in light of help that female family members provide to male farmers. It is obvious that illiterate farmers are going to seek help in everyday matters for example dealing with figures and data in order to successfully cope with farming production (use of fertilizers, pesticides, marketing and subsidies).

				Women's role in agricultural production		
Study area				**They contribute**	**They do not contribute**	***Total***
Alzaqazig	*Formal farmers' educational level*	*illiteracy*	Count	20	10	30
			%	66.7%	33.3%	100.0%
		basic	Count	10	22	32
			%	31.3%	68.7%	100.0%
		average	Count	8	8	16
			%	50.0%	50.0%	100.0%
		advanced	Count	9	13	22
			%	40.9%	59.1%	100.0%
	Total		Count	47	53	100
			%	47.0%	53.0%	100.0%
Almansourah	*Formal farmers' educational level*	*illiteracy*	Count	5	14	19
			%	26.3%	73.7%	100.0%
		basic	Count	5	12	17
			%	29.4%	70.6%	100.0%
		average	Count	6	19	25
			%	24.0%	76.0%	100.0%
		advanced	Count	7	12	19
			%	36.8%	63.2%	100.0%
	Total		Count	23	57	80
			%	28.7%	71.3%	100.0%

Table 6.34: Women's role in agricultural production and male farmers' educational levels (Source: Author's questionnaire, 2006)

Study area	Value	DF	Sig.
Alzaqazig	8.23	3	0.04*
Almansourah	0.94	3	0.81

(* *96% significance level)*

Table 6.35: Chi square test, women's role in agricultural production and male farmers' educational levels

Other evidence for the significant relationship between family contribution in agricultural production and livestock husbandry in the Alzaqazig study area can be seen from Tables 6.36 and 6.37. As it has been confirmed by many authors and studies (Abdelkader, 1997; Haredy, 1998; Arab Organisation for Agricultural Development, 1999; Briggs *et al.,* 2003, Robinson, 2004), livestock husbandry in developing countries

Study area			*Livestock husbandry* Yes	No	*Total*
Alzaqazig	*Family*[1] *contribution to agricultural production*	**They contribute**	67 93.1%	5 6.9%	72 100%
		They do not	23 82.1%	5 17.9%	28 100%
	Total		87 87%	13 13%	100 100%
Almansourah	*Family contribution to agricultural production*	**They contribute**	30 75%	10 25%	40 100%
		They do not	26 65%	14 35%	40 100%
	Total		56 70%	24 30%	80 100%

Table 6.36: Family contribution in agricultural production and livestock husbandry in the two study areas (Source: Author's questionnaire, 2006)

[1] Household members other than the male farmer.

Study area	Value	DF	Sig.
Alzaqazig	2.67	1	0.1
Almansourah	0.95	1	0.23

Table 6.37: Chi square test, family contribution in agricultural production and livestock husbandry in the two study areas

in general and rural Egypt in particular is one of the most important tasks in women's contribution to farming activities. This study's results and analyses have confirmed this fact which could help to explain land-use change in the study area particularly in the Alzaqazig study area as the relationship between family contribution to agricultural production and livestock husbandry tended to be significant (p=0.1, 90% significance level).

The analysis highlights possible effects of family contribution and particularly the role of rural women in land-use change and agricultural production. In the following paragraphs, further investigation regarding women's contribution in agricultural production and other farming activities will be presented. Fertilizer and pesticide use have been considered earlier in this chapter as main farming practices in irrigated agriculture. Therefore, taking into account the relationship between these practices and women's contribution will further help assessing the role of rural women and identify the significant differences between the two study areas. Male dominance in rural areas of the Nile Delta and other parts of rural Egypt makes women's contribution in decision-making very weak (Mohammed, pers. comm., 2006). However, the desperate need for help from illiterate or low level educated farmers forces them to ask for assistance from family members, including women, although this contribution does not appear in any official or formal statistics. Tables 6.38, 6.39, 6.40 and 6.41 further confirm this line of reasoning.

Study Area				*Fertilizer use*		*Total*
				Yes	No	
Alzaqazig	*Women's contribution in agricultural production*	Yes	Count	34	13	47
			%	72.3%	27.7%	100%
		No	Count	48	5	53
			%	90.6%	9.4%	100%
	Total		Count	82	18	100
			%	82%	18%	100%
Alamnsourah	*Women's contribution in agricultural production*	Yes	Count	7	5	12
			%	58.3%	41.7%	100%
		No	Count	62	6	68
			%	91.2%	8.8%	100%
	Total		Count	69	11	80
			%	86.3%	13.7%	100%

Table 6.38: Women's contribution in agricultural production and fertilizers use in the two study areas (Source: Author's questionnaire, 2006)

study area	**Value**	**DF**	**Sig.**
Alzaqazig	**5.6**	**1**	**0.02***
Almansourah	**9.2**	**1**	**0.01$^+$**

(* 98% significance level; $^+$ 99% significance level)

Table 6.39: Chi square test, women's contribution in agricultural production and fertilizer use in the two study areas

Study Area				*pesticide use*		*Total*
				Yes	No	
Alzaqazig	*Women's contribution in agricultural production*	Yes	Count	32	15	47
			%	68.1%	31.9%	100%
		No	Count	45	8	53
			%	84.9%	15.1%	100%
		Total	Count	77	23	100
			%	77%	23%	100%
Almansourah	*Women's contribution in agricultural production*	Yes	Count	7	5	12
			%	58.3%	41.7%	100%
		No	Count	51	17	68
			%	75%	25%	100%
		Total	Count	58	22	80
			%	72.5%	27.5%	100%

Table 6.40: Women's contribution in agricultural production and pesticides use in the two study areas (Source: Author's questionnaire, 2006)

Study area	Value	DF	Sig.
Alzaqazig	7.9	1	0.005*
Almansourah	9.3	1	0.01^{+}

(99.95% significance level; + 99% significance level)*

Table 6.41: Chi square test, women's contribution in agricultural production and pesticides use in the two study areas

Chi square tests for the relationship between rural women's role in agricultural production and use of fertilizers have confirmed (Tables 6.38 and 6.39) the existence of a positive significant connection between rural women's contribution and farm use of fertilizers in both study areas (in Alzaqazig p=0.02 and in Almansourah p=0.01). Also the figures in Tables 6.40 and 6.41 show a positive significant relationship between rural women's contribution to agricultural production and pesticide use in farming practices in Alzaqazig (p=0.005) and Almansourah (p=0.01). These results confirm that rural women in the Nile Delta play an important role in some farming practices such as fertilizer and pesticide use (Alozabie, 1997; Ahmed, 1999). In this context, two questions can be asked. Firstly, are farmers in both study areas able to manage their usual daily farming practices and activities without women's contribution in agricultural production? Since the relationship between women's contribution in agricultural production and some farming practices (fertilizer and pesticide use) is significant in both study areas (Alzaqazig and Almansourah), how does this affect land-use change in the two study areas?

The answer to the first question is that as long as farmers are not prepared to pay for alternative employment, this decision will affect their income dramatically because they are unable to continue in their farming work without women's involvement. On the other hand, although the role of women in some farming practices such as fertilizer and pesticide use in both study areas is significant, farmers in Almansourah are able to manage their daily farming activities because of the higher educational level they have, and the provision of better educational and agricultural extension facilities in Almansourah in comparison with Alzaqazig. However, in case of absence of rural women's contribution in agricultural production in the Alzaqazig study area, farmers will most likely change their farm production from crops that require more labour to crops that require less employment (from wheat to Egyptian clover for example). The reason for this change is due to either the lack of required employment or the tendency to save employment costs as an attempt to achieve extra income. In summary, rural women's contribution in agricultural production is fundamental in both study areas

(Alzaqazig and Almansourah) and is expected to be one of the most important drivers affecting land-use change later on (see Chapter 10) when ranking the importance of driving forces and responses in affecting land-use change in the two study areas.

6.5 Conclusions

This chapter presented an analysis and discussion of the key driving forces assumed to affect land-use change in the two study areas in the Nile Delta. Based on the hypotheses of this study outlined in Chapter 2, this chapter attempted to examine the relationship between each of the possible driving forces and land-use change in the two study areas, and identify the most important ones.

Three main categories of driving forces were included in the DPSIR framework: physical drivers, economic drivers as well as social and cultural drivers. Each category of these drivers has been divided into a number of indicators. Section 6.2.2 discussed the need for irrigation water as the main physical driver. Fertilizer use and pesticide use have been analysed and discussed in connection with other economic and social and cultural drivers in Sections 6.3 and 6.4. Four economic indicators were analysed and discussed in Sections 6.3.1 and 6.3.2. These indicators were: government subsidies, subsidies from private sources, transportation availability and transportation cost as a percentage of the total agricultural costs. The analysis and discussion in Section 6.4 focused on three indicators of social and cultural drivers. These indicators were: population growth, farmers' educational levels and rural women's contribution to agricultural production.

The statistical analysis showed the following results:

- *Transportation availability and cost*: there was a significant relationship between transportation availability and cost and land-use change in Almansourah but not in Alzaqazig.
- *Population growth*: results from section 6.4 showed the importance of population growth in affecting land-use change in the two study areas.
- *Farmers' formal educational levels*: the relationship between farmer's formal educational levels and agricultural rotation was significant in Almansourah and not significant in Alzaqazig. There was also significant relationship between farmer's formal educational levels and family role in agricultural production in Alzaqazig. However, the relationship between farmer's formal educational levels and manure recycling was significant in Almansourah and not significant in Alzaqazig.
- *Subsidies from private source*: the relationship between subsidies from private sources and land-use change was significant in Alzaqazig and not significant in Almansourah.
- *Women's contribution to agricultural production*: there was significant relationship between women's contribution to agricultural production and fertilizer and pesticide use in both study areas (Alzaqazig and Almansourah).

In the next chapter, the analysis and discussion will be focusing on two main pressures on land-use in the two study areas: soil salinisation and area affected by desertification.

Chapter 7: Pressure indicators: results and discussion

7.1 Introduction

The analysis and discussion in Chapter 6 focused on driving forces that affect land-use change in the two study areas. The results presented in Chapter 6 highlighted the importance of multi-causality in the explanation and discussion of drivers and suggested that there were significant differences between the two study areas in terms of causes of land-use change, and that these drivers exerted different types of pressures on agricultural land. The role of climate change, globalisation and the WTO in affecting land-use change in developing countries and arid and semi-arid areas in particular was outlined in Chapter 2.

Based on the causal links between the DPSIR framework elements, pressures on land-use as defined in Chapter 2 are the causes of problems resulting from the driving forces (Lambin *et al.*, 2003; Bach, 2004). For example, the increase in population density puts more pressure on resource use, labour availability and quantity of resources. Thus, identifying the causes of land-use change requires a comprehensive understanding of the interaction between factors that affect decision-making on land-use. Causes of land-use change have been grouped into two main categories (see Chapter 2): proximate or direct causes and underlying causes. While the first group of these causes represent human activities or immediate actions that originate from intended land-use and that are directly affecting land cover and involve a physical action and generally operate at the local level, the latter causes are formed by a complex of social, economic, demographic, technological, cultural, political, and biophysical variables that represent initial conditions in human-environment relations. They originate from regional or even global levels and are often exogenous to the local communities (Lambin *et al.,* 2003). In the context of dealing with these factors as main components of the DPSIR framework, a set of indicators that represent them were presented as a checklist of the domain, sub-domain, and indicators required for measuring the contents of the proposed DPSIR framework (see Chapter 3). Pressure indicators discussed in this chapter are, in particular, soil salinity and areas affected by desertification.

7.2 Soil salinity

7.2.1 Soil salinity in the Nile Delta

Most of the irrigated lands in Egypt (2.95M ha) are in the Nile Delta (Abbott and Leeds-Harrison, 1998). An early soil survey indicated that the percentages of salt affected soils relative to total cultivated lands was 60% in the Lower Delta, 25% in the Middle Delta, 20% in the Upper Delta and Middle Egypt, and 25% in the Upper Egypt (Aboukhaled *et al.*, 1975). A recent inventory concluded that almost 35% of the agricultural lands (1 M ha) in Egypt suffers from salinity (Kotb *et al.,* 2000).

Salt-affected soils, in spite of their scattered occurrence, mainly exist in the northern part of the Nile Delta. In the Mediterranean coastal plains and Lower Delta, an excessive rate of groundwater withdrawal has resulted in a large drop in the water table and, as a consequence, sea water has intruded into aquifers. The main reasons for soil salinity in these areas involve some irrigation with brackish groundwater more particularly, inadequate field drainage (Kotb *et al.,* 2000).

Farmers in the Nile Delta, in common with many in the Middle East, have adopted the reuse of drainage water as a means for providing better supply (Farmer respondents 12, 21, 112). There is no problem with reintroduced salinity, as this has not reached critical levels. However, interviewing local farmers from the Alzaqazig study area suggested that they are experienced in dealing with soil salinity (Farmer respondent 12, 21). A particular cause for concern amongst rural farming communities however is the use of sewage effect since they are the ones who are in most contact with such polluted waters for their domestic and household needs. Farmers are happy to use water with reused drainage water, or even direct drainage water (as unofficial drainage water reuse), since they value the nutrients introduced by sewage elements. They are also concerned about the possibility of industrial toxins, since they have no way of identifying whether they are present or not (FAO, 2005; Gouda, pers. comm., 2005).

Before describing salinization problems of each study area and indicating possible solutions that farmers adopt, it is important to explain that there are two causes of soil salinization in the Nile Delta which apply in both Almansourah and Alzaqazig. Irrigation with brackish water causes salts to accumulate in the crop root zone and, as a result, available water in the soil for the crop is reduced (Gouda, pers. comm., 2005). The other type of soil salinity occurs when there is poor drainage: a shallow groundwater table exists and, as a result of upward movement of water containing salts, evaporation leads to salt accumulation in the top soil. In permeable soils, soil salinisation due to high water table can be controlled by the installation of a drainage system (Kotb *et al.,* 2000).

The severity of the salinization problem has forced both the government and private sector to work jointly to reduce production losses from drainage-impacted lands. For instance, the Egyptian Public Authority for Drainage Projects (EPADP) has installed a network of subsurface drainage in 50% of the total cultivated areas in Egypt and, as a result, crop yields have increased after completion of the first phase of tile drainage projects on 0.25 M ha of the Nile Valley and Delta (EPADP, 1994).

Another salinisation study was carried out by the Monitoring and Evaluation Project (MEP) of the National Drainage Programme (NDP) which investigated 15 sample areas. Three different cases were recognized: new areas that were considered saline and where subsurface drainage was provided for the first time; non-saline areas where subsurface drainage was provided for the first time; and rehabilitation areas where a new system of subsurface drainage will be needed to replace the old one. The results showed that after four years drainage in the new non-saline areas, the extent of saline soils decreased from about 40 percent to only 6 percent. Similarly, the affected saline lands have decreased from nearly 100 percent to 70 percent within two years in the new saline areas (MEP Final Report, NDP, 2001).

In an attempt to tackle soil salinization at the national level in general and the Nile Delta particularly, two approaches have been followed. The first approach was directed by the government and necessitated the installation of a subsurface drainage system, land levelling and application of gypsum. The second approach was mitigation by farmers at the field level and depended on growing rice, a salt tolerant crop. However, the government has tried to counter this approach because of the significant amount of irrigation water required for rice cultivation.

7.2.2 Soil salinity in the two study areas

Due to the lack of data available from the questionnaire about soil salinization, data from other sources available will be used in this context to establish the most important differences between Alzaqazig and Almansourah and how this affects land-use change. The Drainage Research Institute (DRI) in Egypt defined the average salinity of drainage water in the Nile Delta during the year 1992-1993 and categorized it into seven classes (Figure 7.1). Such data show that Almansourah is located in a saline area of 750-1000 ppm and Alzaqazig is located in an area where the average salinity of drainage water is between 1000 and 1500 ppm. This affects the type of crop cultivated in both areas in terms of crop tolerance to salinity. Therefore, more salt tolerate crops are to be expected in the Alzaqazig area than Almansourah. On the other hand, almost 100% of the farmers in both study areas have reported that as well as cultivating rice, they also grow more salt sensitive crops such as maize and cotton in summer and wheat, barley and Egyptian clover (Berseem) in the winter season (author's questionnaire, 2006).

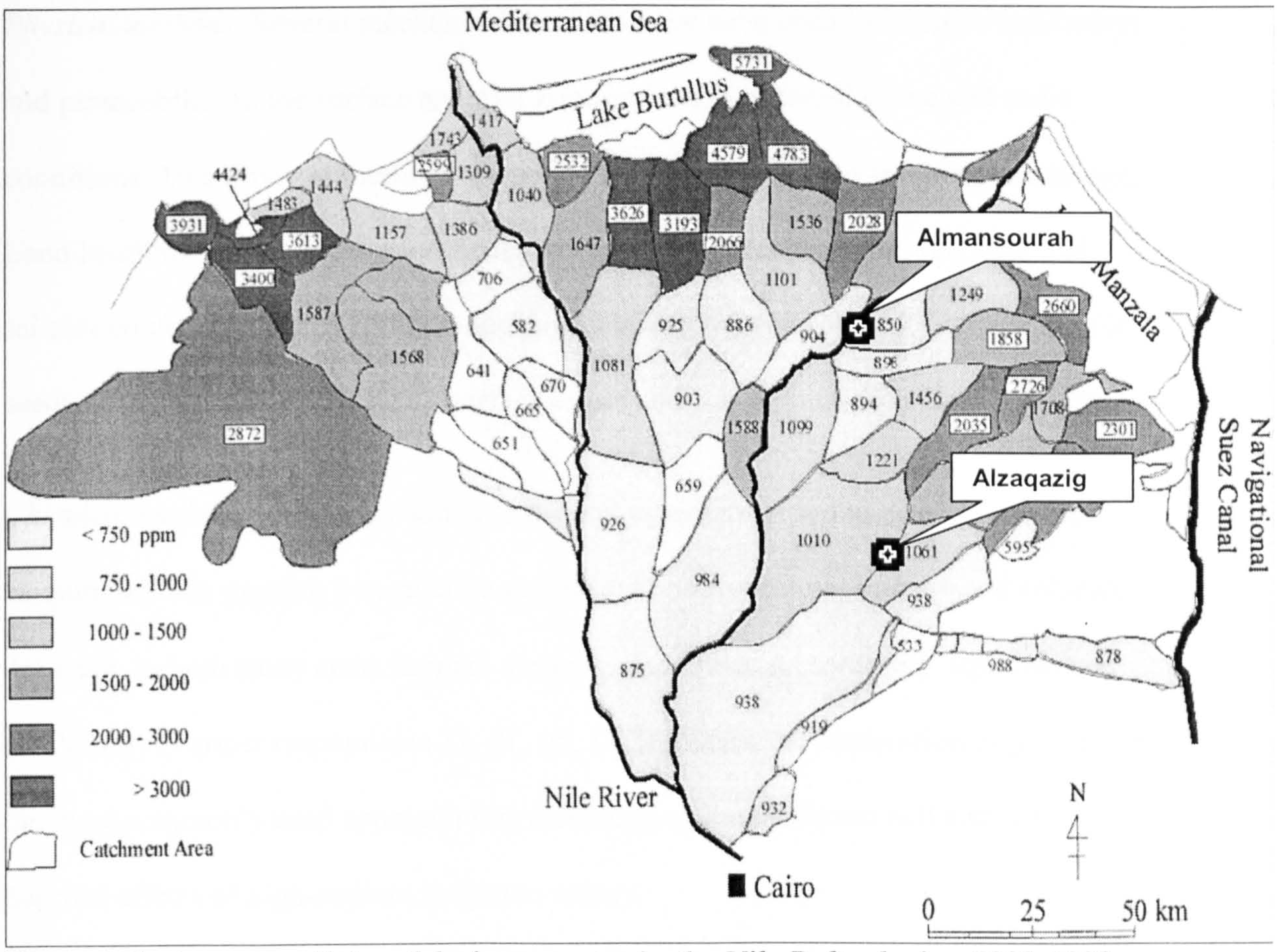


Figure 7.1: Average salinity of drainage water in the Nile Delta during 1992-1993

(Source: DRI, 1994)

In an interview with one of the experts in soil science and land reclamation from the Alzaqazig area (Gouda, pers. comm., 2005) confirmed that the majority of farmers in Alzaqazig have taken actions to improve soil quality in cooperation with the agricultural cooperatives, using several methods to control soil salinity and sodicity. These practices can be summarised as: hydro-technical, physical and chemical methods.

Hydro-technical methods: salt accumulation is removed from the root zone either by mechanical means or leaching. This technique relies on having permeable soils and a good drainage system.

Physical methods: Several mechanical methods have been used to improve infiltration and permeability in the surface and root zone and thus to control saline and sodic conditions. Two physical methods are used for this purpose, land levelling and tillage. Land levelling helps a more consistent application of water for better leaching and salinity control. Tillage is another mechanical operation that is usually carried out for seedbed preparation, breaking up surface crusts and soil permeability improvement.

Chemical methods: chemicals added to the soil commonly used to provide soluble calcium include gypsum (i.e. calcium chloride) to improve soil structure and enhance drainage. In both study areas farmers used gypsum due to its solubility, low cost and availability (Farmer respondents 12, 21, 95, 112). Indeed, the application of gypsum is the most commonly used approach for reclaiming sodium-affected soil and reducing the harmful effects of high-sodium irrigation waters.

It is clear from the discussion above that soil salinity is an important pressure affecting land-use change in the two study areas. However, this problem is more severe in the Alzaqazig study area as it affects farmers' decisions in choosing their crops (Farmer respondents 12, 21). In addition, the adjacent location of Alzaqazig to the eastern desert has added more pressures on land-use. The next section, therefore, will focus on the area affected by desertification, particularly in the Alzaqazig study area.

7.3 Area affected by desertification

Being located in the arid and semi-arid zones, Egypt is severely affected by various types and forms of desertification resulting from climatic variations and human activities and their interactions (Herrman and Hutchinson, 2005). Human activities include unsustainable management of available resources as well as inappropriate policies, plans and legislations. As mentioned in Chapter 4, Egypt covers an area of about 1 M km^2, out of which about of 76,500 km^2 (7.6% of the total area) is inhabited, and the remaining area (92.4%) is desert. The total area of cultivation is mainly concentrated in the Nile Valley and Nile Delta and, to a lesser extent, in limited patches distributed all over Egypt (Hegazi *et al.*, 2005).

Desertification problems in Egypt are extremely serious both in terms of the area affected and the millions of people who suffer the consequences. In the context of this study, desertification is the loss of agricultural land caused by either climate change, human activities or both [(1)]. One question was posed in the questionnaire about loss of agricultural land during the last 20 years and another about gain due to reclamation. As expected, the results showed that there were differences between Alzaqazig and Almansourah. Table 7.1 and Figure 7.2 present data on the farmers who confirmed that they lost agricultural land due to desertification in both study areas. Much of the discussion below will focus on the Alzaqazig study area in terms of the possible desertification and underlying reasons. In particular, 10% of farmers in the Alzaqazig study area have lost farmland to desertification. Further investigation reveals that the

[1] There have been many definitions and meanings for "desertification" by different researchers and institutions. While the United Nations Convention to Combat Desertification (UNCCD) defined desertification as "*Land degradation in arid, semi arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities*" (UNCCD, 1992: Article 1), other sources have emphasised more the political, economic, social and cultural factors that affect desertification process. An example of the latter conceptualisation is the World Commission on Environment and Development's definition of desertification which suggested that desertification is "*the process whereby productive arid and semi-arid land is rendered economically unproductive*" (cited in Wilson and Juntti, 2005: 25).

distribution of the affected farmers by desertification was as follows: seven were from the village of Ghazalah to the east of Alzaqazig and close to desert land, two farmers were from the village of Burdeen in the south of Alzaqazig and also adjacent to desert, and only one farmer came from Al-nakhaas village in the western area of Alzaqazig which is further from the desert.

Study area		***Lost Farmland to desertification***		
		Yes	No	**Total**
Alzaqazig	Count	10	90	100
	%	10%	90%	100%
Almansourah	Count	4	76	80
	%	5%	95%	100%
Total	Count	14	166	180
	%	7.8%	92.2%	100%

Table 7.1: Lost farmland (desertification) in the two study areas

(Source: Author's questionnaire, 2006)

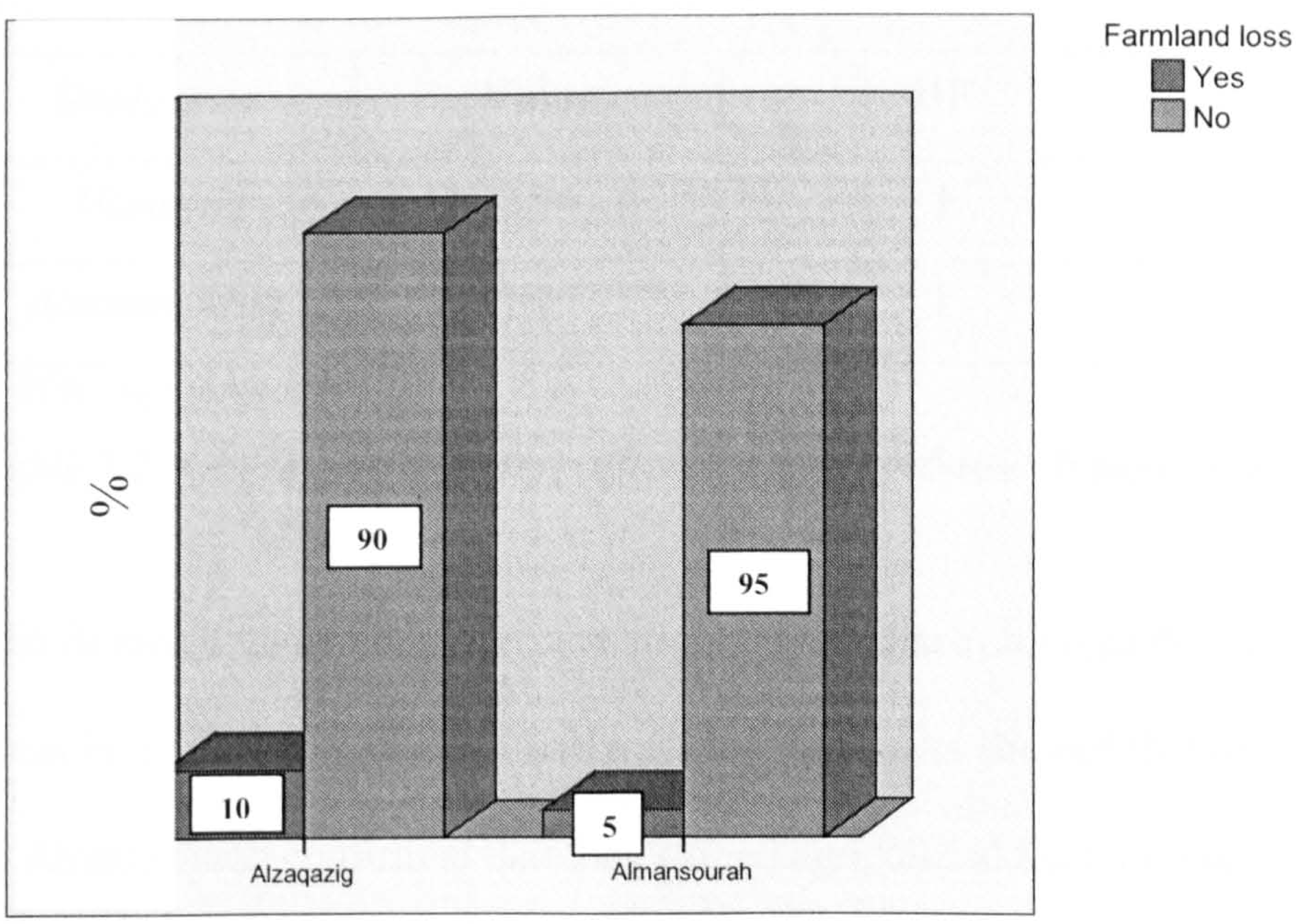


Figure 7.2: Lost farmland (desertification) in the two study areas

(Source: Author's questionnaire, 2006)

To find out the nature of the relationship between desertification and land-use change in the two study areas, a Chi square test was carried out. The results in Table 7.2 show that there has been a significant relationship between desertification and land-use change in Alzaqazig (p=0.09) while the relationship between desertification and land-use change was not significant in Almansourah (p=0.3). The reasons for the significant relationship in Alzaqazig may be linked to two reasons: the first is the location of Alzaqazig near the Egyptian Eastern Desert, which makes the fields of this rural area more vulnerable to the desert climate. Therefore, crops planted are subject to many factors such as irrigation water availability and high levels of soil salinity leading farmers to change their crops into more tolerant ones such as rice. Desertification in Almansourah is less of a problem. The reasons for this could be due to higher rainfall and the fertile soils with a range of organic matter content which has evolved as a result of several generations of cropping.

Study area	Value	DF	Sig.
Alzaqazig	3.06	1	0.09*
Almansourah	1.07	1	0.30

(91% significance level)*

Table 7.2: Chi square test, desertification and land-use change in the two study areas

The farmland gained due to reclamation and purchase amongst farmers in both study areas in the last 20 years was analysed and the results showed that only 8.7% of farmers in Almansourah confirmed that they gained agricultural land compared with14% of farmers in Alzaqazig (Table 7.3 and Figure 7.3).

Study Area		***Gained Farmland***		
		Yes	**No**	***Total***
Alzaqazig	Count	14	86	100
	%	14%	86%	100%
Almansourah	Count	7	73	80
	%	8.7%	91.3%	100%
Total	Count	21	159	180
	%	11.7%	88.3%	100%

Table 7.3: Gained farmland in the two study areas

(Source: Author's questionnaire, 2006)

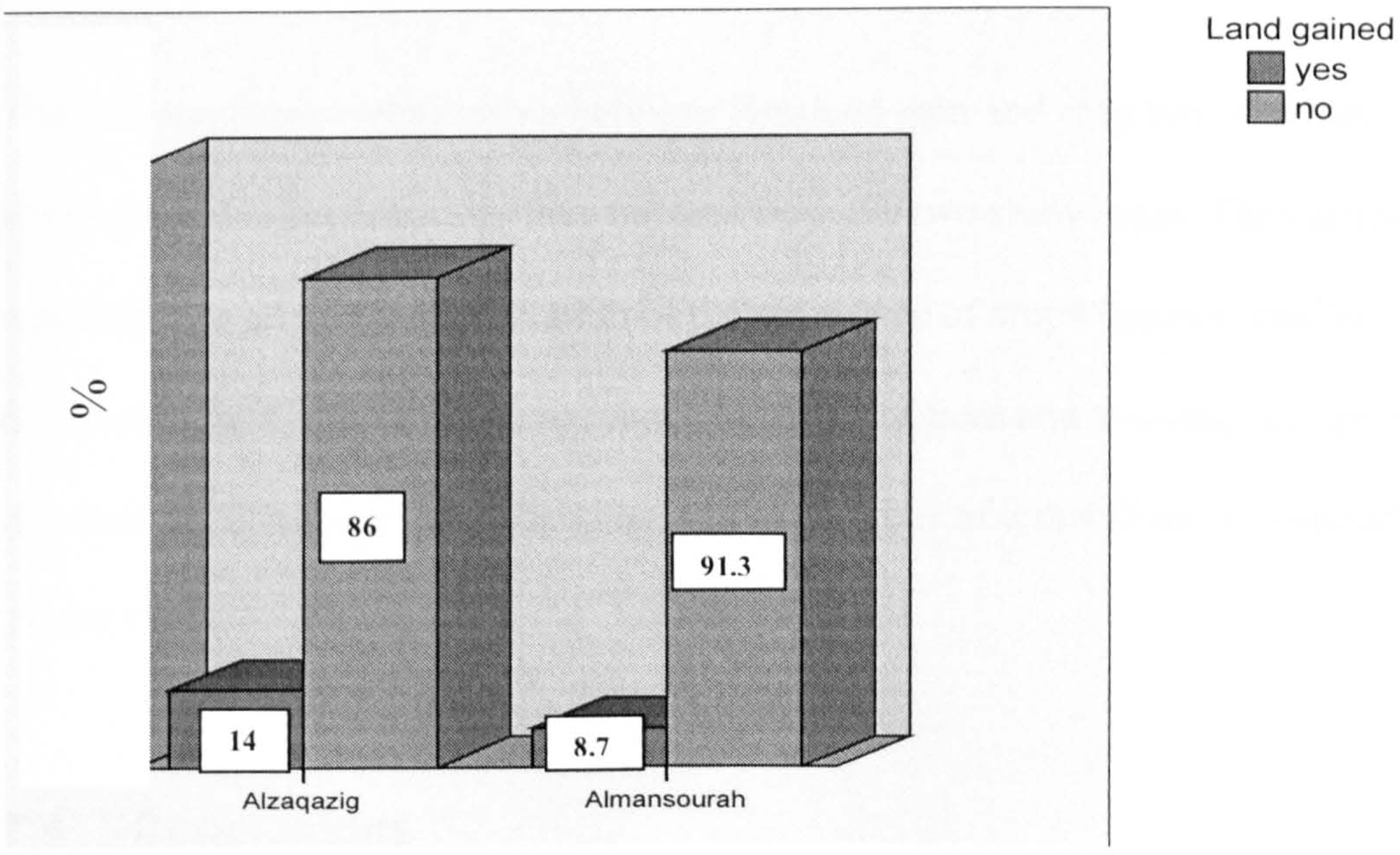


Figure 7.3: Gained farmland in the two study areas

(Source: Author's questionnaire, 2006)

The data reflect the current state of land reclamation projects in Alzaqazig (new land), and explain the relatively high percentage of farmers who stated that had gained new farmland as part of government policy to encourage people to invest and live in desert lands. On the other hand, farmers in the Almansourah study area gained farmland by either buying from others or changing the use of the land from non-agricultural to agricultural use (Imam, pers. comm., 2005; Ahmed, pers. comm., 2005).

The results also showed the absence of any significant relationship between farmland gain and land-use change in the two study areas (see Table 7.4).

Study area	Value	DF	Sig.
Alzaqazig	1.32	1	0.37
Almansourah	0.91	1	0.39

Table 7.4: Chi square test, farmland gain and land-use change in the two study areas

The non significant relationship between farmland gain and crop type changes in both study areas was explained by four farmers from the two study areas. They argued that it was linked to continuing cultivation of the same type of crops farmers used to cultivate on existing land, due to their experience in such practices and avoiding any potential risk that could emerge from changing into other types of crops (Farmer respondent 12, 21, 95,112).

7.4 Conclusions

This chapter discussed soil salinization and desertification as the two possible pressure indicators for land-use change in the two study areas. It started by introducing the definition and meaning of pressures affecting land-use change in the context of the DPSIR framework adopted for this study. Section 7.2 discussed the soil salinity problem in the Nile Delta in general and in the two study areas in particular. Data and information available for this study showed that the Alzaqazig study area is under more pressure in terms of soil salinity than Almansourah. Farmers in the two areas followed different types of methods to control soil salinity in their farms, including: hydro-technical methods, physical methods and chemical methods. In Section 7.3, the analysis and discussion focused on areas affected by desertification. The section discussed the desertification problem in Egypt overall, and discussed different definitions of desertification. The results obtained from the analysis showed that there was a significant relationship between desertification and land-use change in Alzaqazig, while the relationship between desertification and land-use change was not significant in Almansourah.

These pressures will change the current state of land-use in the two study areas. It is, therefore, important to analyse and explain the current state of land-use and possible changes resulting from the mentioned pressures. This issue is the subject of the next chapter.

Chapter 8: State of land-use and impacts: results and discussion

8.1 Introduction

The definition of state of land encompasses the extent of different types of land-use such as crop types, urban areas, water surfaces as well as the area affected by desertification. The discussion in Chapter 4 highlighted key physical, human and agricultural characteristics of Egypt and the Nile Delta in general, and described changes in land-use in the two study areas in particular. The present chapter will explain in more detail how the various driving forces discussed in Chapter 6 are affecting changes in land-use and the impact resulting from these changes. The discussion focused on the number of farmers and their economic, social and cultural characteristics as part of the investigation of the driving forces component in the DPSIR framework. In this chapter, the focus will be on the number of farmers involved in land-use change to act as a surrogate for the areas involved. This assumption is quite acceptable because the majority of farmers owned less than 2 ha.

Impacts on land-use, as mentioned in Chapter 2, refer to changes that occur in the environment and people which lead the society to respond. These changes could result from human-induced modification to the physical and socio-economic structure of land-use characteristics or be due to ecological effects. Although it is possible to divide the impacts on land-use in a given study area into two main categories, namely, biodiversity loss and economic damage, the other impacts such as desertification, reduced crop productivity, degradation of soils, and increased prices for farming commodities are also important. The extent and reasons of changes in the state of land will be discussed in Section 8.2 based on the questionnaire data, interviews and remotely sensed data. Section 8.3 will discuss and analyse one of the impacts of land-use change in the two study areas: expenditure on soil degradation as a percentage of the total agricultural costs.

8.2 State of land-use: changes, reasons and explanation

Section 4.6 presented key descriptions of land-use changes in the two study areas over the period 1984-2003. It was shown that crop patterns have experienced major changes with regard to both their geographical distribution and extent. In the Almansourah study area, key changes were an increase in cotton area and decrease in rice, maize and other crops (Figures 4.19 and 4.20; Table 4.14). In contrast, the Alzaqazig study area has experienced an increase in cotton and rice with a minor increase in maize fields (Figures 4.21 and 4.22; Table 4.15). In this section the discussion will focus on the reasons for land-use changes as perceived from the farmers' point-of-view.

Analysis of the questionnaire data found that 65% of farmers in Alzaqazig and 28% of farmers in Almansourah had changed their land-use during the period 1984-2003 (Table 8.1 and Figure 8.1). The next paragraph will explore why considerably more farmers in Alzaqazig changed their land-use than in Almansourah and reasons for change.

Study area		Land-use change		
		Yes	No	*Total*
Alzaqazig	Count	65	35	100
	%	65%	35%	100%
Almansourah	Count	22	58	80
	%	27.5%	72.5%	100%
Total	Count	87	93	180
	%	48.3%	51.7%	100%

Table 8.1: Land-use change in the two study areas

(Source: Author's questionnaire, 2006)

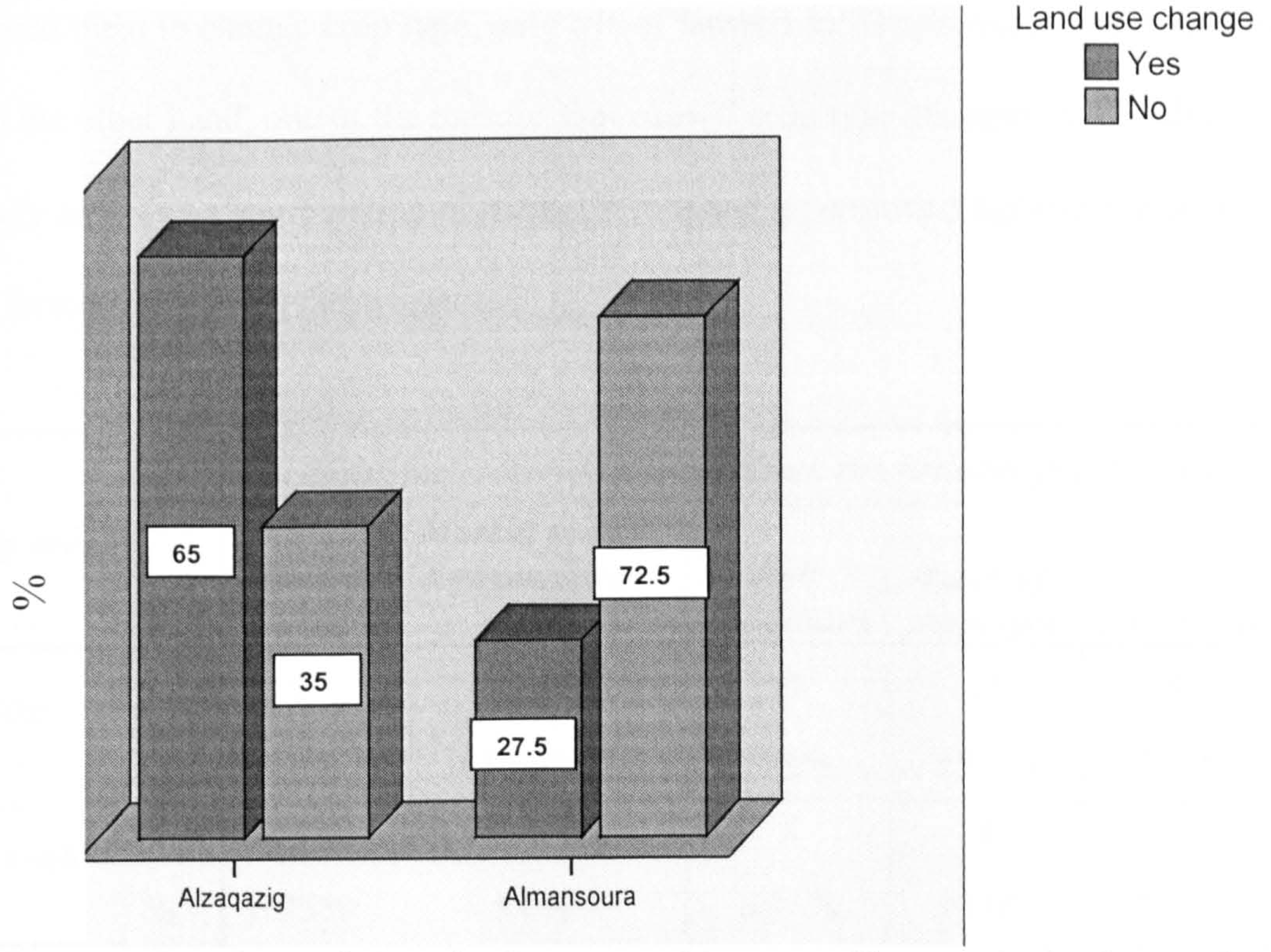


Figure 8.1: Land-use change in the two study areas (Source: Author's questionnaire, 2006)

Table 8.2 and Figure 8.2 show possible reasons for farmers changing crop type over time in each study area. Farmers gave different reasons for the change: in the Alzaqazig study area, 27% of farmers highlighted the importance of soil conditions as one of the main reasons for crop changes in the area. In Almansourah, meanwhile, only 6% of farmers argued that soil conditions were one of the reasons for land-use change. While 15% of farmers in Alzaqazig suggested that lack of employment as a cause for changes in land-use, 10% of farmers in Almansourah suggested that this reason was playing crucial role in crop type changes. While 9% of farmers in the Alzaqazig study area argued that market prices (see Chapter 9 for more detail) were one of the reasons that forced them to change crop type, only 6% of farmers in Almansourah confirmed this. On the other hand, one of the reasons that caused crop type changes in the Almansourah study area was a combination of market prices and government agricultural policy (5% of farmers suggested these reasons).

Study area		***Reasons for crop type change from the farmers point-of-view***					***Total***
		Market prices	***Market prices &government policy***	***Soil conditions***	***Lack of employee***	***no change***	
Alzaqazig	Count	9	14	27	15	35	100
	%	9.0%	14.0%	27.0%	15.0%	35.0%	100.0%
Almansourah	Count	5	4	5	8	58	80
	%	6.25%	5.0%	6.25%	10.0%	72.5%	100.0%
Total	Count	14	18	32	23	93	180
	%	7.7%	10.0%	17.8%	12.8%	51.7%	100.0%

Table 8.2: Reasons for land use change in the two study areas

(Source: Author's questionnaire, 2006)

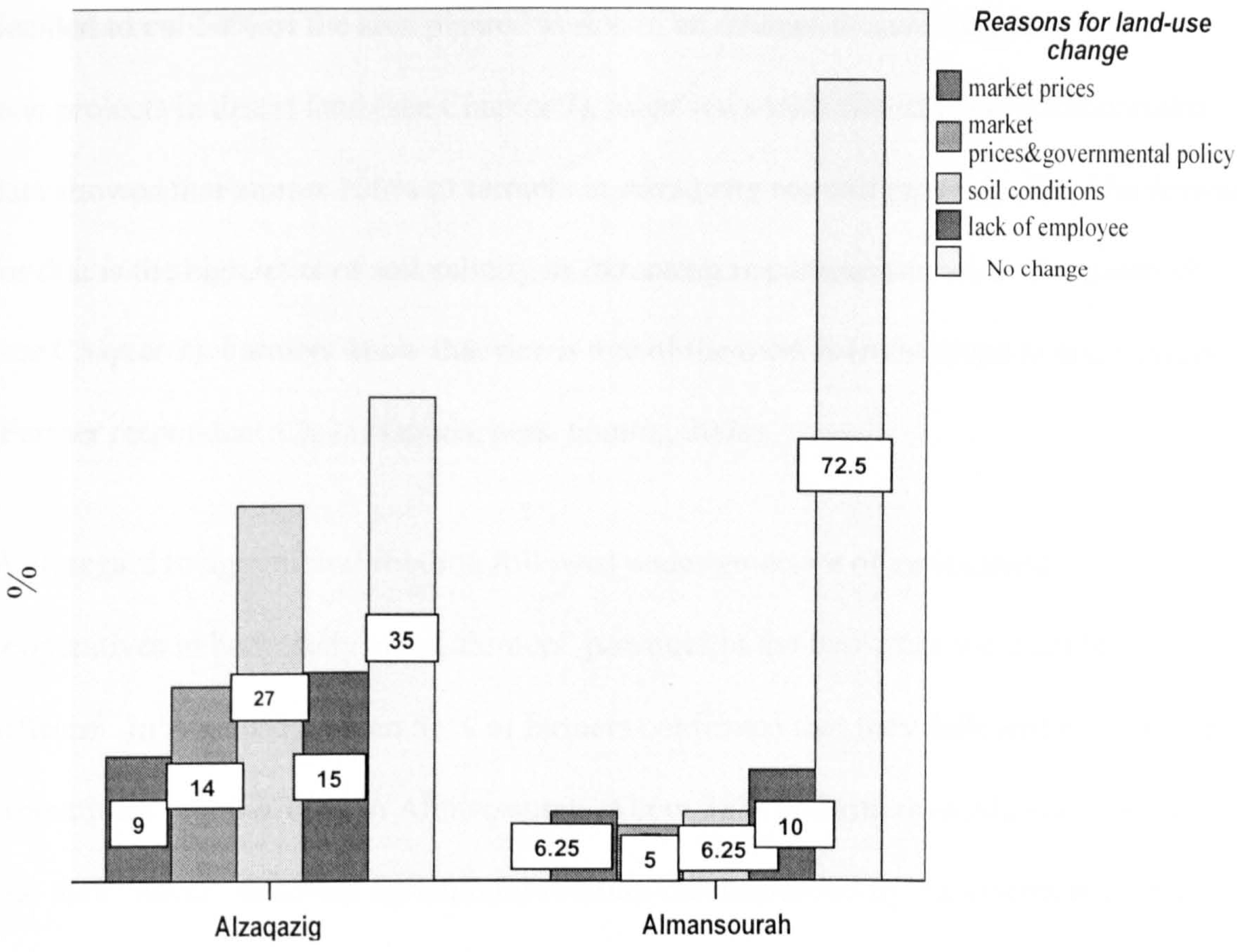


Figure 8.2: Reasons for crop type changes from the farmers' point-of-view over time in the two study areas (Source: Author's questionnaire, 2006)

The difference between Alzaqazig and Almansourah can be explained in terms of the length of time which the land has been cultivated. In Almansourah, as an old settled agricultural area, farmers have considerable experience growing crops that suit their soil and climate conditions and dealing with other factors that could adversely affect their production and income (Farmer respondent 112, 122). In contrast, the Alzaqazig area is new agricultural land, where farmers are still trying to determine the most suitable crops to cultivate on their farms. A clear example of a difficult decision was whether to continue to cultivate rice in the Alzaqazig study area. Although the government has decided to cut 50% of the area planted to rice in an attempt to save irrigation water for new projects in desert land (see Chapter 7), interviews with farmers and questionnaire data showed that almost 100% of farmers in Alzaqazig are still growing rice. The reason for that is the high level of soil salinity in Alzaqazig in comparison with Almansourah (see Chapter 7). Farmers know that rice is one of the most tolerant crops to soil salinity (Farmer respondent 12, 21; Gouda, pers. comm., 2005).

With regard to agricultural rotation followed under guidance of agricultural cooperatives in both study areas, farmers' practices in the two areas were slightly different. In Alzaqazig, about 53% of farmers confirmed that they followed the rotation "sometimes" against 60% in Almansourah. About 38% of farmers in Alzaqazig argued that they "never" followed agricultural rotation recommended by the cooperative in the rural community, whereas 33% of Almansourah farmers said that they never followed the rotation whatsoever. Further information on crop rotation is shown in Tables 6.16-6.18 which show how consistent farmers are in following the agricultural rotation in the two study areas.

The description of land-use change presented in Chapter 4, and results and discussion outlined in Chapter 6 highlighted that there have been several causes for land-use change in the two study areas during the period 1984-2003. Although some of these reasons were similar in the two study areas, others played a significant role in affecting land-use change in Alzaqazig but not in Almansourah, and *vice-versa*. To clarify this issue further, a synthesis of all drivers that have affected changes in land-use will be presented next.

The statistical analysis conducted in Chapter 6 has revealed the nature of the relationships between changes in land-use and the various physical, economic as well as social and cultural driving forces associated with these changes. Based on the results presented in Chapter 6, key driving forces that have affected land-use change in the Alzaqazig study area were:

1. The need for irrigation water.
2. Subsidies from private sources.
3. Population growth.
4. Family contribution to agricultural production.

In the Almansourah study area, meanwhile, land-use change was mainly affected by the following drivers:

1. The need for irrigation water.
2. Transportation availability.
3. Transportation costs.
4. Population growth.
5. Farmers' educational levels.

Chapter 10 will further discuss the importance of driving focres and responces that have affected land-use change in the research region in general, and in the two study areas in particular.

Having analysed the state of land-use in the two study areas, discussed the reasons of change in the farmers piont-of-view, and suggested the possible drivers that affect land-use change in each study area, changes in the state of land-use will have environmental or economic *impacts* on the social and economic performance of society. The next section will, therefore, discuss expenditure on reducing soil degredation as one of the imapcts of land-use change in the two study areas.

8.3 Impacts of land-use change

As highlighted in Chapter 3, economic performance has been considered as an important sub-domain of the impact component in the DPSIR framework for this study. The sole indicator which represented impacts of land-use change in the two study areas is expenditure on reducing soil degradation as a percentage of the total agricultural costs. This section will examine expenditure on reducing soil degradation as the main impact of land-use change in the two study areas.

Table 8.3 and Figure 8.3 show numbers and percentages of farmers with their expenditure on reducing soil degradation in the two study areas. The majority of farmers in the Almansourah study area (more than three quarters) declared that they spent 5-10% of the total agricultural costs on reducing soil degradation against over half of farmers in Alzaqazig. It can be seen from the data that, while almost half of farmers in the Alzaqazig study area argued that they spent less than 5% of total agricultural costs on reducing soil degradation on their farms, only a quarter of farmers in Almansourah reported that they spent less than 5% on reducing soil degradation.

Study area		*Expenditure on reducing soil degradation*		
		< 5%	5 -10%	*Total*
Alzaqazig	Count	45	55	100
	%	45%	55%	100%
Almansourah	Count	19	61	80
	%	23.8%	76.2%	100%
Total	Count	64	116	180
	%	35.6%	64.4%	100%

Table 8.3: Expenditure on reducing soil degradation in the two study areas

(Source: Author's questionnaire, 2006)

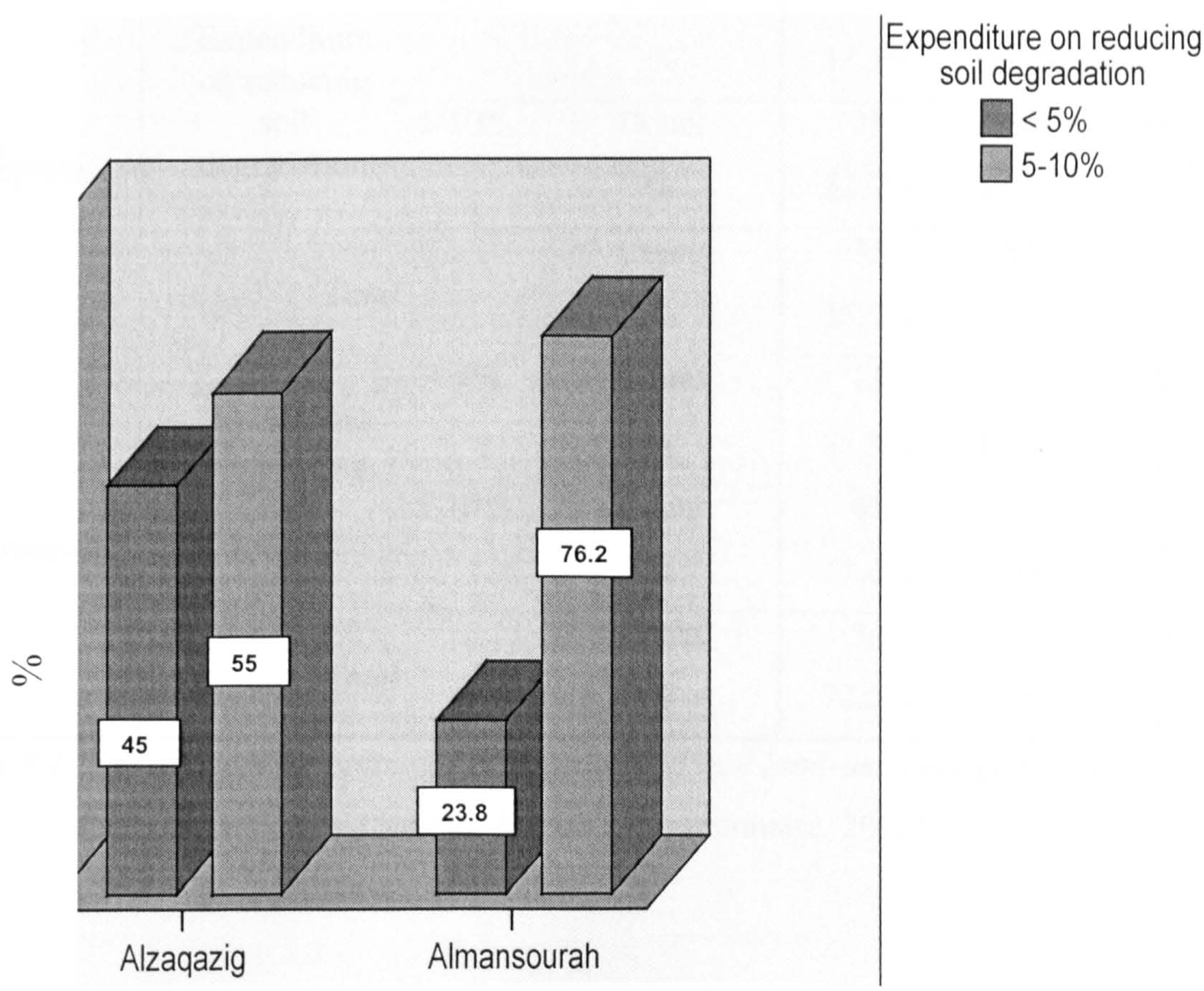


Figure 8.3: Proportion of farmers and their expenditure on reducing soil degradation in the two study areas (Source: Author's questionnaire, 2006)

Yet, the important issue in this context is to find out the nature of the relationships between expenditure on reducing soil degradation and land-use change in each study area. The statistical analysis in Tables 8.4 and 8.5 suggests that there is a significant relationship between land-use change and expenditure on reducing soil degradation in the Alzaqazig study area (p=0.00). In contrast, the association between land-use change and expenditure on reducing soil degradation is not statistically significant in Almansourah (p=0.19).

Study area				***land-use change*** No	Yes	***Total***
Alzaqazig	Expenditure on reducing soil degradation	< 5%	Count	6	39	45
			%	13.3%	86.7%	100.0 %
		5-10%	Count	29	26	55
			%	52.7%	47.3%	100.0 %
	Total		Count	35	65	100
			%	35.0%	65.0%	100.0 %
Almansourah	Expenditure on reducing soil degradation	< 5%	Count	11	8	19
			%	57.9%	42.1%	100.0 %
		5-10%	Count	47	14	61
			%	77.0%	23.0%	100.0 %
	Total		Count	58	22	80
			%	72.5%	27.5%	100.0 %

Table 8.4: Expenditure on redcing soil degradation and land-use change in the two study areas (Source: Author's questionnaire, 2006)

Study area	Value	DF	Sig.
Alzaqazig	15.2	1	0.00*
Almansourah	1.8	1	0.19

(100% significance level)*

Table 8.5: Chi square test, expenditure on redcing soil degradation and land-use change in the two study areas

These results are consistent with the conclusions presented in Chapter 7. The significant relationship between land-use change and expenditure on reducing soil degradation in Alzaqazig has two main reasons. First, pressures on land-use resulting from soil salinity in Alzaqazig (Chapter 7) force farmers to tackle this problem and, therefore, they are prepared to spend a proportion of the total agricultural costs on improving their soil farms structure and reducing degradation. Second, pressure on land-use resulting from desertification in Alzaqazig (Chapter 7) makes farmers more responsive to the seriousness of land degradation in the area and, for this reason, they try to stop desert encroachment by spending money on reducing soil degradation and improving soil structures (e.g. chemical and organic input; see Chapter 7). However, the majority of farmers (87%) in Alzaqazig can only afford to spend a minimal amount on soil improvement because they are relatively poor compared to those in Almansourah (Farmer respondent 12, 21, 22).

8.4 Conclusions

This chapter has discussed the state of land-use (based on the number of farmers who changed their land-use and their reasons) and impacts resulting from pressure indicators discussed in Chapter 7. At the outset, *state of land-use* and *impacts* of land-use change were defined in the context of the DPSIR framework adopted in this study. Section 8.2 discussed- in addition to the description presented in Chapter 4- changes in land-use, reasons and explanation for these changes in each study area. The discussion highlighted the main reasons for land-use change from the farmers' point-of- view in the two study areas. It concluded that lack of employment, soil condition as well as market prices and governmental agricultural policy were key reasons for land-use change in the two study areas from the farmers' point-of-view.

Of particular note, the statistical analysis showed that there were differences between Alzaqazig and Almansourah in terms of the driving forces that affect land-use change as Chapter 6 highlighted. The need for irrigation water, subsidies from private sources, population growth and family contribution to agricultural production were key drivers for land-use change in the Alzaqazig study area. The need for irrigation water, transportation availability, transportation cost, population growth and formal farmers' educational levels were key drivers for land-use change in the Almansourah study area.

In Section 8.3, the main impact of land-use change discussed in this study was expenditure on reducing soil degradation. The statistical analysis suggested a significant relationship between expenditure on reducing soil degradation and land-use change in Alzaqazig and a non significant one in Almansourah.

Having discussed driving forces, pressure indicators, state and impacts of land-use change in the two study areas, it is important to investigate how farmers react and respond in the context of the DPSIR framework applied in this study. The discussion and analysis of possible *responses* by farmers will be presented in next chapter.

Chapter 9: Response indicators: results and discussion

9.1 Introduction

This chapter discusses the responses of farmers to the drivers and pressures in the land-use change system in terms of undertaking training to acquire new skills. Chapter 6 has discussed how a multiplicity of driving forces including physical, economic as well as social and cultural indicators are interconnected to influence changes in land-use in the two study areas. In Chapter 7, the discussion highlighted the importance of two key pressures: soil salinity and area affected by desertification. These pressures affected the current state of land-use and, therefore, led to changes in crop patterns and area of crops in both study areas. Chapter 8, meanwhile, analysed the reasons for these changes and discussed expenditure on reducing soil degradation as a key impact of land-use change in the two study areas. As a result of these pressures, and in an attempt to minimise the effects of degradation, the different responses which may be made by farmers or taken by decision-makers are important. Responses taken by decision-makers were discussed in Section 4.5 as changes in agricultural policies. This chapter will focus on the responses made by farmers i.e. the land managers.

The response component of the DPSIR framework relates to the actions taken by individuals or the wider community. In the widest sense, the responses may include regulatory action, expenditure on environmental research, public opinion, and changes in management strategies including further training (Cinnirella *et al.*, 2003; Bach, 2004). Responses in the context of the DPSIR framework should be designed to act on the pressures, but may at the same time also have an impact modifying the indicators of state. In this study, two key response indicators are discussed comprehensively: changes in the governmental agricultural policy (1984-2003; Section 4.5) and new skills and training undertaken by farmers (Section 9.2).

9.2 New skills and training received by farmers

The aim of this section is to assess the importance of new skills and training received by farmers in the two study areas, and to determine the significance of the relationships between this indicator and farming practices such as agricultural rotation, fertilizer and pesticide use. This study hypothesises that new skills and training received by farmers have a significant relationship with farming practices such as agricultural rotation, fertilizer and pesticide use and, ultimately, may affect land-use change.

The importance of training and skills received by farmers in agricultural production has been discussed by various studies. A study carried out by Oxenham *et al.* (2002) in several African countries concluded that a combination of livelihood skills training and adult literacy education helps improve poor people's livelihoods. Firstly, there is a widely noted "empowerment effect" that learners acquire enhanced confidence and social resources which help them take initiatives to improve their livelihoods. Second, literacy and numerical skills are a clear advantage in market transactions in the informal economy, and therefore especially important for entrepreneurship. Thirdly, more productive agricultural or livestock practices result from learning new vocational skills. These effects should not be seen as isolated but as arising from complementary inputs.

For example, not only are skills and market opportunity needed, but there must also be access to credit.

An evaluation report on an adult literacy training project in Egypt made this important distinction: "*quite often the needs assessment identified the need for income generation opportunities of which vocational training might be a part... An additional challenge is not to confuse income-generation with vocational training. Both are often important, but people developing vocational skills often need further support (such as with credit schemes and marketing) to be able to generate income*" (cited in Oxenham *et al.*, 2002: 7).

There are several crucial questions about skills training and land-use change. For example, how do new skills and training received by farmers in the two study areas affect their farming practices and influence land-use change? How could this indicator tackle problems resulting from the pressures put on the land? And how could this indicator improve the current state of land-use? Answers to these questions will be presented after analysing the data available from the questionnaire and discussing the significance of the relationships between new skills and training received by farmers in the two study areas, and other factors that represent farming practices and crop type change.

Table 9.1 and Figure 9.1 show the figures and percentages of farmers who stated that they received new skills and training related to their farming practices (67% in Alzaqazig and only 12.5% in Almansourah). In response to a question about the type of training, 33% of farmers in Alzaqazig had received training in crop production, 19% in irrigation systems and livestock husbandry and only 6% in crop production and livestock husbandry. On the other hand, only 4% of farmers in Almansourah confirmed they received training and new skills about crop production.

Study area		*New skills and training received by farmers*		*Total*
		Yes	No	
Alzaqazig	Count	67	33	100
	%	67.0%	33.0%	100.0%
Almansoura	Count	10	70	80
	%	12.5%	87.5%	100.0%
Total	Count	77	103	180
	%	42.8%	57.2%	100.0%

Table 9.1: New skills and training received by farmers in the two study areas

(Source: Author's questionnaire, 2006)

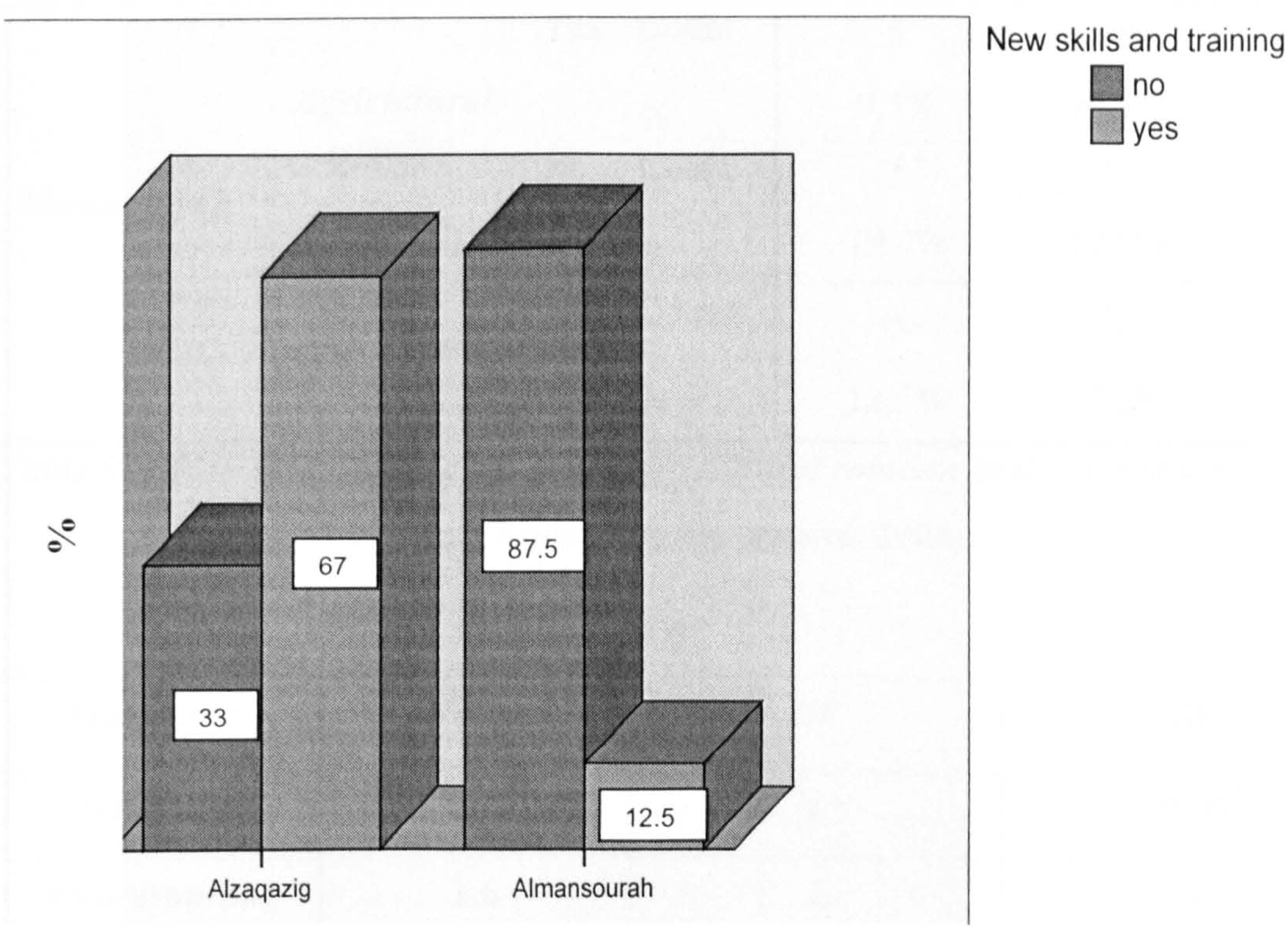


Figure 9.1: Training and skills received by farmers in the two study areas

(Source: Author's questionnaire, 2006)

In order to assess the significance of the relationship between new skills and training received by farmers and the agricultural rotation they follow, a Chi square test is required. While Table 9.2 shows figures and percentages of farmers who received new skills and training with the agricultural rotation they follow, Table 9.3 shows the significance of this relationship.

Study area				*New skills and training received by farmers* Yes	No	*Total*
Alzaqazig	*Agricultural rotation*	Yes	Count	51	11	62
			%	82.3%	17.7%	100.0%
		No	Count	16	22	38
			%	42.1%	57.9%	100.0%
	Total		Count	67	33	100
			%	67%	33%	100.0%
Almansourah	*Agricultural rotation*	Yes	Count	5	49	54
			%	9.3%	90.7%	100.0%
		No	Count	5	21	26
			%	19.2%	80.8%	100.0%
	Total		Count	10	70	80
			%	12.5%	87.5%	100.0%

Table 9.2: New skills and training and agricultural rotation in the two study areas

(Source: Author's questionnaire, 2006)

Study area	Value	DF	Sig.
Alzaqazig	**17.2**	**1**	**0.00***
Almansourah	**1.6**	**1**	**0.2**

(100% significance level)*

Table 9.3: Chi square test, skills and training and agricultural rotation

Results from Table 9.3 confirm the significant link between new skills and training received by farmers and agricultural rotation in Alzaqazig (p=0.00). On the other hand, the relationship is not significant in Almansourah (p=0.2). Therefore, these results confirm that the effectiveness of training and skills on some of farmers' practices may depend on geographical location and indirectly on the farmers' level of educational attainment (Sections 2.4.6 and 6.4.2). Further analyses of the nature of the relationship between new skills and training and different farming practices will be needed to confirm the previous evidence. To investigate the relationship between the new skills and training received by farmers in the study area and fertilizer and pesticide use in particular, Tables 9.4 and 9.6 show figures and percentages of farmers in the two study areas and Tables 9.5 and 9.7 show the significance of these relationships.

Study area				*New skills and training received by farmers* Yes	No	*Total*
Alzaqazig	*Fertilizer use*	Yes	Count	50	26	76
			%	65.8%	34.2%	100.0%
		No	Count	17	7	24
			%	70.8%	29.2%	100.0%
	Total		Count	67	33	100
			%	67.0%	33.0%	100.0%
Almansourah	*Fertilizer use*	Yes	Count	5	54	59
			%	8.5%	91.5%	100.0%
		No	Count	5	16	21
			%	23.8%	76.2%	100.0%
	Total		Count	10	70	80
			%	12.5%	87.5%	100.0%

Table 9.4: ***New skills and training and fertilizer use in the two study areas***

(Source: Author's questionnaire, 2006)

Study area	Value	DF	Sig.
Alzaqazig	0.2	1	0.6
Almansourah	3.3	1	0.04*

(96% significance level)*

Table 9.5: Chi square test, new skills and training and fertilizer use in the two study areas

Study area				*New skills and training received by farmers* Yes	No	*Total*
Alzaqazig	Pesticide use	Yes	Count	49	28	77
			%	63.6%	36.4%	100.0%
		No	Count	18	5	23
			%	78.3%	21.7%	100.0%
	Total		Count	67	33	100
			%	67.0%	33.0%	100.0%
Almansoura	Pesticide use	Yes	Count	5	53	58
			%	8.6%	91.4%	100.0%
		No	Count	5	17	22
			%	22.7%	77.3%	100.0%
	Total		Count	10	70	80
			%	12.5%	87.5%	100.0%

Table 9.6: New skills and training and pesticide use in the two study areas

(Source: Author's questionnaire, 2006)

Study area	Value	DF	Sig.
Alzaqazig	1.7	1	0.2
Almansourah	2.9	1	0.09

Table 9.7: Chi square test, new skills and training and pesticide use in the two study areas

The results shown above confirm the hypothesis stated earlier with reference to the significant relationship between new skills and training received by farmers and their farming practices in Alzaqazig, and disprove the significance of this relationship in

Almansourah. The relationship between new skills and training received by farmers and fertilizer use was significant in Alzaqazig (p=0.04) and not significant in Almansourah (p=0.6). Data in Table 9.7 also show that the association between new skills and training received by farmers and pesticide use tended to be significant in Alzaqazig (p=0.09, *91% significance level*) and was not significant in Almansourah (p=0.2). The differences between the two areas can be explained in light of the differences in their soil types. Farmers in Alzaqazig were more enthusiastic about increasing their crop production by applying fertilizers and using pesticides in the same way they have been trained and obtained the new skills (Farmer respondent 21, 22). On the other hand, farmers in Almansourah, as they have been cultivating their long settled land for many generations, obtained their skills and experience informally from many sources and most of the new skills and training they gained recently did not affect their farming practices significantly as in Alzaqazig. Before testing the relationship between new skills and training received by farmers and agricultural extension, a review of the current status of farmers receiving agricultural extension is shown in Table 9.8 and Figure 9.2.

Study area		***Agricultural extension***			***Total***
		No, never	In the past only	Yes, now	
Alzaqazig	Count	12	16	72	100
	%	12%	16.0%	72.0%	100.0%
Almansourah	Count	24	20	36	80
	%	30.0%	25.0%	45.0%	100.0%
Total	Count	32	36	112	180
	%	17.8%	20.0%	62.2%	100.0%

Table 9.8: Farmers in receipt of agricultural extension in the two study areas

(Source: Author's questionnaire, 2006)

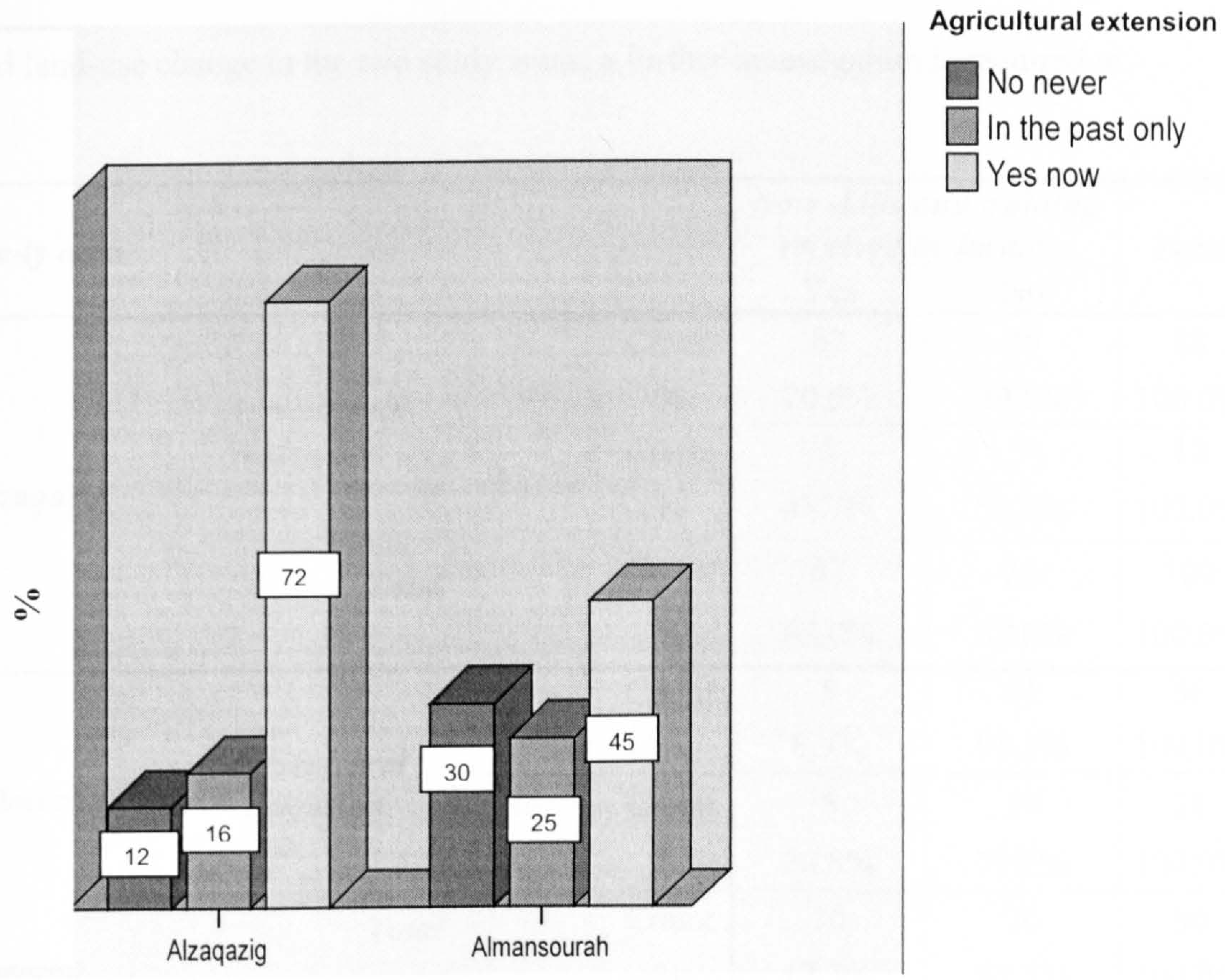


Figure 9.2: Farmers in receipt of agricultural extension in the two study areas
(Source: Author's questionnaire, 2006)

Results shown in Tables 9.9 and 9.10 reveal that farmers in Alzaqazig used their new skills and training gained by contacting staff from the agricultural extension department to help in their farming practices (Farmer respondent 12, 21, 22). The relationship between new skills and training received by farmers and the agricultural extension they gained was significant in Alzqazig (p= 0.05). In contrast, this relationship was not significant in Almansourah (p=0. 2). The farming practices in Alzaqazig have been more influenced by new skills and training compared with those in Almansourah for similar reasons to those set out above.

With reference to the relationship between new skills and training received by farmers and land-use change in the two study areas, a further investigation is required to

Study area				*New skills and training received by farmers*		*Total*
				Yes	No	
Alzaqazig	*Agricultural extension*	Yes	Count	62	26	88
			%	70.5%	29.5%	100.0%
		No	Count	5	7	12
			%	41.7%	58.3%	100.0%
	Total		Count	67	33	100
			%	67.0%	33.0%	100.0%
Almansourah	*Agricultural extension*	Yes	Count	5	51	56
			%	8.9%	91.1%	100.0%
		No	Count	5	19	24
			%	20.8%	79.2%	100.0%
	Total		Count	10	70	80
			%	12.5%	87.5%	100.0%

Table 9.9: New skills and training and agricultural extension in the two study areas

(Source: Author's questionnaire, 2006)

Study area	**Value**	**DF**	**Sig.**
Alzaqazig	**4**	**1**	**0.05***
Almansourah	**2.1**	**1**	**0.2**

(95% significance level)*

Table 9.10: Chi square test, new skills and training and agricultural extension in the two study areas

examine the nature of this relationship. Table 9.11 shows the numbers and percentages of farmers regarding new skills and training they received and land-use change, and Table 9.12 shows the significance of this relationship.

The statistical analysis suggested a significant relationship between new skills and training received by farmers and land-use change in Alzaqazig (p=0.02) and no

Study area				*Land-use change* Yes	No	*Total*
Alzaqazig	*New skills and training received by farmers*	Yes	Count	38	29	67
			%	56.7%	43.3%	100.0%
		No	Count	27	6	33
			%	81.8%	18.2%	100.0%
	Total		Count	65	35	100
			%	65.0%	35.0%	100.0%
Almansourah	*New skills and training received by farmers*	Yes	Count	5	5	10
			%	50.0%	50.0%	100.0%
		No	Count	17	53	70
			%	24.3%	75.7%	100.0%
	Total		Count	22	58	80
			%	27.5%	72.5%	100%

Table 9.11: New skills and training received by farmers and land-use change in the two study areas (Source: Author's questionnaire, 2006)

Study area	**Value**	**DF**	**Sig.**
Alzaqazig	**6.5**	**1**	**0.02***
Almansourah	**2.6**	**1**	**0.12**

(98% significance level)*

Table 9.12: Chi square test, new skills and training received by farmers and land-use change in the two study areas

significant relationship in Almansourah (p=0.12). These results can be explained in light of the level of response between farmers in the two areas. Farmers in the Alzaqazig area were more in need of agricultural extension and support from the agricultural extension department because of their insufficient experience in agricultural production in comparison with those in the Almansourah area. As a result, farmers in the Alzaqaig area have used their new skills and training provided by the agricultural extension services to decide what crops to cultivate on their farms (Farmer respondent 21, 22). Farmers in Almansourah, however, used the experience they gained through many generations of cultivation in the area to determine what are the most appropriate crops for their farms (Farmer respondent 112, 121).

9.3 Conclusions

This chapter has discussed a key response indicator affecting land-use change in the two study areas: new skills and training received by farmers. Section 9.1 introduced meaning of responses in the context of the DPSIR framework adopted in this thesis. In Section 9.2, the discussion focused on the assessment of new skills and training as a response towards some farming practices such as agricultural rotation and fertilizer and pesticide use. This section also examined the relationship between new skills and training received by farmers and land-use change in the two study areas. The statistical analysis suggested a significant relationship between new skills and training received by farmers and land-use change in Alzaqazig and a no significant relationship in Almansourah.

Having discussed the five components of the DPSIR framework in Chapters 6, 7, 8 and 9, the next chapter will discuss the importance of driving force and response indicators in affecting land-use change at the research region level (macro-level). Chapter 10 also will rank the importance of driving forces and responses in affecting land-use change in the research region (Probit analysis).

Chapter 10: Synthesis and ranking of driving forces and responses affecting land-use change

10.1 Introduction

In Chapters 6-9 the aim was to investigate land-use change over time in the Nile Delta area by analysing the driving forces, pressures, state of land, impacts and responses. A comprehensive study and explanation of key indicators and the dynamic relationships between them was also presented. Chapter 6 discussed the physical, economic as well as social and cultural drivers that influenced land-use change in the area in general, whereas the discussion in Chapter 9 focused on the responses made by farmers in the two study areas, Alzaqazig and Almansourah.

The first aim of this chapter is to synthesise and assess the importance of the key drivers and responses that are included in the DPSIR framework for the wider research region[1] as represented by the two study areas. So far the influence of the indicators has been examined for each of the study areas individually (Chapters 6 and 9). In contrast, in Sections 10.2 -10.9 the discussion of the various indicators will be presented for the research region based on the data aggregated from the two study areas. The second aim of this chapter is to rank the driving force and response indicators as they facilitate or

[1] The research region is defined as the area of 60 by 60 km in the Nile Delta, which includes the two study areas, as delimited on the remote sensing image presented in Chapter 3.

constrain actions taken by farmers (see Chapters 6 and 9). The focus will be on determining the relative significance that each indicator has on land-use change. Each indicator will be set up as an independent variable with land-use change as the dependent variable and a relative ranking will be determined for each indicator using the Probit analysis model (Section 10.9), based on the analysis described in Sections 10.2, 10.3 and 10.5 - 8. In many ways this relative ranking of the drivers affecting land-use change can be considered to be the culmination of the analysis in this thesis.

Before considering the importance of the drivers such as subsidies, transport costs and population growth it is important to underline the fundamental need for irrigation water in the research region. Water is limiting resource in agricultural production in the region as in other parts of Egypt (Section 6.2.2). The reason is the absence of effective rainfall or ground water available for agricultural irrigation. When considering different types of land-use, farmers consider crop water requirements, relative input and output prices, and the institutions that determine how water is allocated among farmers. For example, when the farm level cost of water is low relative to the cost of water conserving inputs, farmers do not invest much time or effort in improving the efficiency with which water is delivered to fields unless those efforts increase yield (Wichelns, 1999). Given the similarity between farmers' behaviour in using the irrigation system in each area, the other indicators included in the DPSIR framework must be examined to provide an explanation of the changes occurring in land-use.

10.2 Agricultural subsidies

In this section, the influence of both government subsidies and subsidies from private sources on land-use change in the research region will be discussed. Table 10.1 shows the frequency of farmers in the research region receiving a government subsidy and undertaking land-use change.

Indicator			*Land-use change* Yes	No	*Total*
Government subsidy	Yes	Count	23	16	39
		%	59.0%	41.0%	100.0%
	No	Count	64	77	141
		%	45.4%	54.6%	100.0%
Total		Count	87	93	180
		%	48.3%	51.7%	100.0%

Table 10.1: Government subsidies and land-use change in the research region
(Source: Author's questionnaire, 2006)

Chi square test	Value	DF	Sig.
Chi square	2.26	1	0.13

Table 10.2: Chi square test: government subsidies and land-use change in the research region

Table 10.2 shows that there is no significant relationship between government subsidy and land-use change in the research region (p=0.13). There were, therefore, other drivers which caused changes in land-use in the research region. The following paragraph will examine the relationship between subsidies from private sources and land-use change.

Table 10.3 shows the number and percentage of farmers in relation to private source subsidies and land-use change in the research region, and Table 10.4 shows the significance of the relationship. The chi square test result suggests that the relationship between private source subsidies and land-use change tended to be significant at 90%

Indicator			***Land-use change***		***Total***
			Yes	No	
Private source subsidies	Yes	Count	47	39	94
		%	54.7%	45.3%	100.0%
	No	Count	40	54	86
		%	42.6%	57.4%	100.0%
Total		Count	87	93	180
		%	48.3%	51.7%	100.0%

Table 10.3: Private source subsidies and land-use change in the research region

(Source: Author's questionnaire, 2006)

Chi square test	Value	DF	Sig.
Chi square	2.63	1	0.1

Table 10.4: Chi square test: private source subsidies and land-use change in the research region

significance level (p=0.1). As a result and as Chapter 6 highlighted, subsidies from private sources played, to some extent, a role in land-use change in the research region and are expected to feature in the relative rankings (see section 10.9). The next section will investigate the role of transportation availability and costs in affecting land-use change in the research region.

10.3 Transportation availability and cost

In this section the importance of both transport indicators will be assessed, namely transportation availability in the agricultural production and cost of farming transportation as a percentage of the total cost of agricultural production. By way of introduction, the statistical analysis in Chapter 6 suggested that land-use change has a significant relationship with transportation availability in Almansourah (p=0.01) and no significant connection in Alzaqazig (p=0.28). Similarly the relationship between transportation cost and land-use change was significant in Almansourah (p=0.00) and not significant in Alzaqazig (p=0.72).

At the macro scale, that is for the research region, Table 10.5 shows the number of farmers with transport availability, as defined earlier, and land-use change. The table shows that transportation availability is not an important driver in affecting land-use change in the research region (Table 10.6, p=0.6).

Indicator			*Land-use change*		*Total*
			Yes	No	
Transportation availability	Yes	Count	39	29	68
		%	57.4%	42.6%	100.0%
	No	Count	48	64	112
		%	42.9%	57.1%	100.0%
Total		Count	87	93	180
		%	48.3%	51.7%	100.0%

Table 10.5: Transportation availability and land-use change in the research region
(Source: Author's questionnaire, 2006)

Chi-square test	Value	DF	Sig.
Chi square	3.6	1	0.6

Table 10.6: Chi square test: transportation availability and land-use change in the research region

Table 10.7 shows the distribution of farmers, their relative cost of transportation as a percentage of the total agricultural production costs, and associated land-use change in the research region. There is a significant relationship between transportation costs and land-use change in the research region (Table 10.8; p=0.04). In other words, transportation cost is one of the important drivers influencing land-use change in the research region. Therefore, it is expected to take a prominent position in the explanation of land-use change when ranking driving force and response indicators (Section 10.9).

			Land-use change		*Total*
			Yes	No	
Transportation costs	<5%	Count	33	22	55
		%	60.0%	40.0%	100.0%
	5-10%	Count	54	71	125
		%	43.2%	56.8%	100.0%
Total		Count	87	93	180
		%	48.3%	51.7%	100.0%

Table 10.7: Transportation cost and land-use change in the research region

(Source: Author's questionnaire, 2006)

Chi square test	Value	DF	Sig.
Chi square	4.32	1	0.04*

(96% significance level)*

Table 10.8: Chi square test: transportation costs and land-use change in the research region

10.4 Population growth

The discussion in Sections 4.3.1 and 6.4.1 highlighted the importance of population growth as one of the key drivers affecting land-use change in both case study areas. Analysis of the satellite images and census data for the two study areas found that the encroachment of urban settlements into agricultural land in the two study areas has been important (Figures 4.2 - 4.5). Further analysis of the remote sensing data of the research region confirmed that many of the rural-urban fringes in the research region had changed from agricultural fields into urban settlements. As discussed in the detailed analysis above, the rate of change in Almansourah was greater compared with Alzaqazig (Table 4.5). Taking into consideration each study area's specific characteristics as mentioned in Chapter 4, population growth in Almansourah has been one of the most important driving forces that has impacted on land-use because it is an important economic centre. This indicator has a lower level in the ranking hierarchy in the Alzaqazig study area because of access to reclaimed land in the desert area. In summary, population growth, and the need to meet the housing demands of the population, is one of the most important drivers that has influenced land-use change throughout the research region.

10.5 Farmers' educational levels

In Section 6.4.2, the discussion focused on the extent to which farmers' educational levels influenced farming practices such as agricultural rotation, fertilizer and pesticide use, and manure recycling in the two study areas. The statistical analysis (Tables 6.23

and 6.24) also suggested a significant relationship between farmers' educational levels and family role in farming practices in the Alzaqazig area (p=0.00). However, this relationship was not significant in Almansourah (p=0.15). In this section, the analysis will determine the nature of the relationship between farmers' educational levels and land-use change in the research region (Table 10.9). Table 10.10 presents the significance of the relationship between farmers' educational levels and land-use change. Chi square test results show a significant link between farmers' educational levels and land-use change in the research region (Table 10.10; p=0.04). This indicator, therefore, appears to play an important role in land-use changes at the regional level and is expected to occupy a high level in the ranking hierarchy as a driver affecting land-use change in the research region.

Indicator			*Land-use change*		*Total*
			Yes	No	
Farmers' educational levels	*illiterate*	Count	31	6	49
		%	63.3%	36.7%	100.0%
	basic	Count	25	24	49
		%	51.0%	49.0%	100.0%
	average	Count	16	25	41
		%	39.0%	61.0%	100.0%
	advanced	Count	15	6	41
		%	36.6%	63.4%	100.0%
Total		Count	87	93	180
		%	48.3%	51.7%	100%

Table 10.9: Farmers' educational levels and land-use change in the research region

(Source: Author's questionnaire, 2006)

Chi square test	Value	DF	Sig.
Chi square	8.205	3	0.04*

*(*96% significance level)*

Table 10.10: Chi square test, farmers' educational levels and land-use change in the research region

10.6 Rural women and their contribution in agriculture

The discussion in Section 6.4.3 highlighted the importance of rural women's contribution to agricultural production and some farming practices such as fertilizer and pesticide use and livestock husbandry in the two study areas (Tables 6.33, 6.35 and 6.37). The statistical analysis suggested a significant relationship between family contribution in agricultural production and land-use change in Alzaqazig but not in Almansourah (Table 6.29). This section will examine the relationship between rural women's contribution in agriculture and land-use change in the research region (Table 10.11).

Indicator			*Land-use change* Yes	*Land-use change* No	*Total*
Rural women's contribution in agriculture	Yes	Count	36	23	59
		%	61.0%	39.0%	100.0%
	No	Count	51	70	121
		%	42.1%	57.9%	100.0%
Total		Count	87	93	180
		%	48.3%	51.7%	100.0%

Table 10.11: Rural women's contribution in agriculture and land-use change in the research region (Source: Author's questionnaire, 2006)

Chi square test	Value	DF	Sig.
Chi square	5.65	1	0.02*

*(*98% significance level)*

Table 10.12: Chi square test, rural women's contribution in agriculture and land-use change in the research region

The link between women's contribution in agriculture and land-use change is significant at the macro scale (Table 10.12; p=0.02) and this finding is in line with many other authors (see Section 6.4.3 for more detail). This indicator is expected to be one of the most important drivers affecting land-use change in the relative ranking of key drivers (Section 10.9).

10.7 New skills and training received by farmers

Section 9.2 discussed the new skills and training received by farmers in the two study areas and its influence on farming practices; agricultural rotation, fertilizer and pesticide use, and ultimately, land-use change. Statistical analysis suggested a significant relationship between new skills and training and farming practice in Alzaqazig whereas in Almansourah a significant relationship was only evident with regard to fertilizer and pesticide use. This section will investigate the nature of the link between new skills and training received by farmers and land-use change in the research region.

Table 10.13 shows the number and percentage of farmers with regards to new skills and training they received and land-use change in the research region. The relationship is not significant in the research region (Table 10.14; p=0.5). This result confirms that this

Indicator			*Land-use change* Yes	No	*Total*
New skills and training received by farmers	Yes	Count	40	38	78
		%	51.3%	48.7%	100.0%
	No	Count	47	55	102
		%	46.1%	53.9%	100.0%
Total		Count	87	93	180
		%	48.3%	51.7%	100.0%

Table 10.13: New skills and training received by farmers and land-use change in the research region (Source: Author's questionnaire, 2006)

Chi square test	Value	DF	Sig.
Chi square	0.48	1	0.5

Table 10.14: Chi square test, new skills and training received by farmers and land-use change in the research region

indicator is not crucial as a response to changes in land-use at the macro scale and, therefore, it is not expected to figure in the ranking hierarchy analysis of driving force and response indicators (Section 10.9).

10.8 Agricultural extension received by farmers

Section 9.2 discussed the importance of agricultural extension as one of the possible responses included in the DPSIR framework. Agricultural extension received by farmers in the two study areas has been investigated in connection with other indicators such as new skills and training received by farmers. The statistical analysis in Section

9.2 suggested a significant link between new skills and training received by farmers and agricultural extension in the Alzaqazig study area (p=0.05) but not in Almansourah (p=0.2). In this section, the discussion will focus on the importance of agricultural extension in affecting land-use change in the research region.

Table 10.15 presents the numbers and percentage of farmers with regard to whether or not they received agricultural extension which affected land-use change in the research region. The relationship was not significant (Table 10.16; p=0.74) and, therefore, a low position is expected in the ranking hierarchy system (Section 10.9).

Indicator			*Land-use change*		*Total*
			Yes	No	
Agricultural extension	Yes	Count	70	73	143
		%	49.0%	51.0%	100.0%
	No	Count	17	20	37
		%	45.9%	54.1%	100.0%
Total		Count	87	93	180
		%	48.3%	51.7%	100.0%

Table 10.15: Agricultural extension and land-use change in the research region

(Source: Author's questionnaire, 2006)

Chi square test	Value	DF	Sig.
Chi square	0.11	1	0.74

Table 10.16: Chi square test, agricultural extension and land-use change in the research region

10.9 Probit model analysis

The main purpose of the Probit model analysis is to rank the relationships between the various driving forces and response indicators as independent variables and land-use change as the dependent variable. Previous authors have employed probability models of factors affecting land-use change (Klin and Alig, 1999; Hite *et al.*, 2000). As such, the Probit results detailed in this section represent the culmination of the research in this thesis, because it has been possible to derive the relative influence of the diverse drivers of land-use change in the research region (macro scale). It is an alternative to regression for dealing with non-metric dependent variables, especially in the case of binary measures (Hair *et al.*, 1995; Robinson, 1998; Maddala, 2001) and is one of the non-linear regression functions of SPSS. The dependent variable, land-use change, was measured using the binary method (existence of land-use change=1 and absence of land-use change=0). All the independent variables were presented as a set of dummy-variable coding except for farmers' educational levels which was coded as a continuous variable.

One of the advantages of the Probit model analysis is the ability to know whether an event (change or not) occurred, and then use the dichotomous value as the dependent variable. From this dichotomous value, the formula predicts its estimate of the probability that the event will or will not occur (Hair *et al.*, 1995). In order to clarify the hypotheses in this section, it has been assumed that land-use change in the research region is influenced in multi-causal ways by all the independent factors which were discussed individually in Sections 10.2, 10.3 and 10.5 - 8:

1. Government subsidy availability
2. Private source subsidies availability
3. Transportation availability
4. Transportation cost
5. Farmers' educational levels
6. Rural women's contribution in agriculture
7. New skills and training received by farmers
8. Agricultural extension received by farmers

Results of the Probit model analysis are presented in Table 10.17. Transportation cost

Parameter	*Parameter Estimate*	*Std. Error*	*P value*	*95% Confidence Interval*	
PROBIT				Lower Bound	Upper Bound
Farmers' educational levels	-0.034	0.016	***0.032*****	-0.065	-0.003
Rural women's contribution in agriculture	0.459	0.247	***0.064****	-0.026	0.944
Transportation availability	0.234	0.208	0.262	-0.175	0.642
Transportation cost	-0.569	0.165	***0.001******	-0.892	-0.246
Governmental subsidy	0.026	0.110	0.816	-0.189	0.241
Private source subsidy	0.209	0.082	***0.011*****	0.049	0.370
New skills and training received by farmers	0.071	0.106	0.504	-0.137	0.279
Agricultural extension received by farmers	-0.334	0.302	0.268	-0.926	0.257

Table 10.17: Probit model results, land-use change and 8 independent indicators
(Source: Author)

(p=0.001), private source subsidies (p=0.01), farmers' educational levels (p=0.03) and rural women's contribution in agriculture (p=0.06) were all found to have significantly contributed to land-use change in the research region. However, transport availability, government subsidies, new skills and training, and agricultural extension received by farmers, did not make a significant contribution in land-use change. These results were confirmed by consideration of individual variables (Sections 10.2, 10.3 and 10.5 – 8). Therefore, transportation cost as a percentage of the total production cost is of paramount importance (p=0.001) in determining land-use change in the research region. Private source subsidies, farmers' educational levels and rural women's contribution in agriculture were also important.

In summary, the relative ranking of driving force and response indicators affecting land-use change in the research region is: transportation cost > private source subsidies > farmers' educational levels > rural women's contribution in agriculture. The importance of each of the four mentioned indicators in affecting agricultural production and land-use change was discussed in a general context in Chapter 2. The following discussion will explain the importance of these economic and social indicators with regard to the research region.

Transportation cost is the most fundamental economic factor that influences land-use patterns and land-use change in the research region (Section 2.4.5); a result which has been confirmed by many authors (Von Thunen, 1826; Rasul *et al.*, 2004). Assuming that farmers try to maximise their revenue, those who live farthest from the market or distribution point adopt a type of land-use that reflects their greater transportation costs.

At the micro-scale, farmers living near one of the main settlements have an advantage over those living further away and could grow high value perishable crops. Similarly at the macro-scale farmers working in the vicinity of Almansourah have easier access to the Cairo agricultural market than those in Alzaqazig. The government has a role to play as it can intervene and improve the current infrastructure of roads and networks so that access is improved throughout the region.

Private source subsidies are another economic factor which plays a role in land-use change in this study. These subsidies increased when changes in agricultural policies took place in the early 1990s (see Chapter 4). The importance of private source subsidies in influencing land-use change was also noted by Lingard (2002) (see Section 2.4.8).

Two factors found to play a crucial role in land-use change in the research region were of a social and cultural nature. Farmers' educational levels in the research region contributed significantly in agricultural production and land-use change as shown in Chapter 6 and this section. These results are in line with other authors and studies that highlighted the importance of education in agricultural production and land-use change (Lockheed *et al.,* 1980; Philips 1994; FAO, 1996; Griliches, 1997; Ibitayo, 2006). The role of rural women's contribution to agriculture was also important. It could be argued that the motivation behind the importance of this indicator in affecting land-use change in the research region and Egypt generally is an economic rather than a social one. Farmers try to seek help from female members of the family in order to save extra cost linked to outsider employment. As a result, and due to the high level of unemployment among women, the contribution of women in agriculture will have an important impact on agricultural production and land-use change. These results suggest that it is economic factors which largely determine land-use change – a result supported by many geographical studies (Kaur and Sharma, 1991; FAO, 1995; Rahman, 2000; Robinson, 2004; Al-Rousan, 2005).

10.10 Conclusions

This chapter has aggregated and ranked the importance of the driving force and response indicators influencing land-use change in the research region. The first aim was to synthesise and assess the importance of the key drivers and responses that were included in the DPSIR framework. The second was to evaluate the relative ranking of driving force and response indicators in affecting land-use change in the research region. Given that water availability is pre-eminent (Section 10.1), Sections 10.2-10.8 discussed the importance of each indicator individually and their relationship with land-use change in the research region. Significant relationships were found with:

1- farmers' educational levels (p=0.04)
2- rural women's contribution to agricultural production (p=0.02)
3- transportation cost as a percentage of the total production cost (p=0.04)
4- private source subsidies tended to be significant (p=0.1)

The relationship between transportation availability, government subsidies, new skills and training, and agricultural extension and land-use change was not found to be significant in the research region.

Probit model analysis ranked the driving forces which influence land-use change in the research region (Section 10.9): transportation cost > private source subsidies > farmers' educational levels > rural women's contribution in agriculture. Economic factors were found to be fundamental, in line with many other geographical studies, although social issues were also important. All these results have been based on applying the DPSIR framework to assess factors that influence land-use change in the two case study areas. However, throughout the analysis it was found that the DPSIR framework is not without problems, in particular with regard to its relatively "mono-dimensional" approach that tends to draw "clear" boundaries around complex patterns and processes. The next chapter will, therefore, critique and discuss key advantages and disadvantages of the DPSIR framework and data sources used in this study.

Chapter 11: Critique of the DPSIR framework and assessment of the quality of data used in this study

11.1 Introduction

The DPSIR framework is central to the research on land-use change discussed in this thesis. This chapter will review some of its strengths and limitations. Its background was explained in Chapter 1 while its history and development, plus a range of its applications, were described in Chapter 2. The inter-relationships between the model's five components, driving force, pressure, state of land-use, impact and response, were discussed in Chapter 3. Following careful consideration of alternative approaches, the DPSIR framework was adopted to facilitate the land-use research which is the focus of this thesis. Justification of its selection to underpin the research set out in this thesis was given in Section 2.5.

The first part of this chapter is a critique of the DPSIR framework. Section 11.2 aims to evaluate whether the DPSIR framework was applied successfully to the semi-arid research region of the Nile Delta with a time scale of about 20 years. It will explore whether the model assisted in highlighting the factors that influenced land-use change in the two study areas. In the final part of the chapter (Section 11.3), the reliability of the five types of data used in this study will be assessed.

As discussed in Chapter 2, the DPSIR conceptual framework facilitates the synthesis of a wide range of types of data and is based on the concept of causality chains which connect human activities with environmental information. One of the model's strengths is to be able to classify and synthesise a wide range of information about the factors affecting land-use change into one of a series of different components, namely driving forces, pressures, state, impacts and responses (EEA, 2002; FAO, 2002; Caeiro *et al.*, 2004; Ewret *et al.*, 2005). However, there are several limitations (see Section 3.5), notably its linear approach and associated problem of dealing with multiple causes. The next section will discuss whether the advantages of using the DPSIR framework outweigh the disadvantages in a land-use change study.

11.2 A DPSIR framework critique

The evaluation of the DPSIR framework will be discussed in the context of whether the aims of the present study have been fulfilled (Section 1.4). As such, consideration will be given to the extent to which the classification and explanation of the factors affecting land-use change in the Nile Delta study region has been achieved. Bakkes *et al.* (2000) commented that research success should be evaluated on the basis of attaining the goals which the framework was asked to achieve, that is in terms of whether there is greater insight into the problem than previously. The critique will be structured as follows:

- Selection of the DPSIR model as a conceptual framework.
- Selection of individual indicators.
- Criteria to determine the success or failure of the DPSIR framework.
- The strengths and weaknesses of applying the DPSIR framework.

As discussed in Chapter 2, there are a range of possible models that can be used to investigate land-use change at a range of scales in a variety of environments. The main aims of this research, as noted in Section1.4, are to contribute towards an understanding of the factors which affect land-use change in a semi-arid area. The ability of the DPSIR framework to include all the possible factors that affect land-use change and categorise them in five causality chain components - as well as organise each component and locate the right indicators in order to measure the effect of each one - made this model a robust one to achieve the main research goals stated earlier in Chapter 1. Critical factors which had to be taken into account ranged from government policies and the national economy at one extreme, to individual farmers (the land managers) and their behaviour and aspirations, as well as cultural and economic factors at the other. The DPSIR conceptual framework was thought to be most appropriate for such a study because it considered the driving force component (as shown in Chapter 3) at the outset.

One of the most important strengths of the DPSIR framework is that it is comprehensive (Peirce, 1998; White *et al.*, 2006). To explain this point further, the five components in the framework comprise a reasonably inclusive set of indicators in the form of checklists for data collection and analysis purposes (Chapter 3). The series of checklists developed for this study were based on many different sources, including the FAO (2002), and were designed to consider all the major factors (comprehensively) that affect land-use change in general. The indicators specified above (Table 3.5) have been utilised in a number of situations and at different scales in Africa, and based on this experience it was decided to use them in this study. Careful consideration was given to each of the indicators for this investigation. Based on the particular circumstances of the Nile Delta, it was decided which ones had to be included and which could be discarded.

No additional indicators needed to be added which suggests that the original lists were comprehensive.

Bach (2004) considered the flexibility of the checklist approach in terms of the model's "impacts" category. He demonstrated that it is not necessary to include all domains and their associated indicators and that some may be superfluous. In this present study, for example, two sub-domains were identified in the impacts component of the DPSIR framework, namely economic performance and biodiversity. However, as the relevant indicators with regard to the biodiversity sub-domain of the impact component were not relevant, they were discarded and the study focussed on understanding the main indicators' included in driving forces, pressures, state, impact and responses.

A fundamental point of the DPSIR framework, confirmed by the experience of this research, was the ability of the method to integrate extremely different types of information and data resources. Five major resources were used to investigate land-use change in the two study areas: remote sensing data; questionnaire data; interview information; participant observation and agricultural census data. In addition, government policy information was also accessed. Analysis of the driving forces was based on information from all five sources. Pressure and state of land-use indicators were examined using all the resources except agricultural census data. The impact component was explored using questionnaire data, while the response component was analysed using questionnaire data, participant observation, interviews and census data. The issue of how to deal with the lack of some relevant data will be dealt with below.

A major strength of the DPSIR framework is its ability to deal with uncertainty. At one level the framework facilitated the study of the interrelationships between the factors that affect land-use change. At another level, sub-models were used to explore the relationships between the origins and consequences of land-use change because of the qualitative nature and descriptive character of the components and associated indicators (Brouwer *et al.*, 2003). For example, a statistical model (Probit model analysis in Chapter 10) was employed to identify the relationship between the different driving forces and responses to land-use change. The technique was very powerful because it enabled the indicators that influence land-use change to be ranked in order of importance. In other words, the DPSIR framework has the capacity to include sub-models where appropriate to explain observed patterns at both the macro and micro scale.

A particular challenge faced in the application of the DPSIR concept in this research was the exact classification of the various factors within the framework. For many factors it was straightforward to decide which category they were in. For example, by definition drivers consist of the needs of individual and institutions that lead to activities that put pressures on the agricultural production and land-use. A farmer's aspirations and behaviour can only be allocated to the driving force component. However, some indicators, as mentioned in Chapter 3, were more ambiguous to classify. For example, the change in agricultural policy was considered as a response in this study, even though it could argued that it is also a driving force component as one of the causes of land-use change (Wilson and Juntti, 2005). However, an agricultural policy is - most of the time - a response taken by the government in order to reduce an increasing pressure or amend a current state. The application of a new agricultural policy, for example, could change the driving forces which in turn put pressures on agricultural production and, therefore, change the current state of land-use. In such a case, a new response would be required either by the government or individuals to reduce the pressure or modify the current state.

A further challenge was the lack of available data required for analysing crucial indicators. For example, the difficulty in obtaining any data about the operation of the irrigation system at the farm scale and particularly the quantity of irrigation water and its scheduling meant that this important indicator had to be omitted from the main DPSIR framework. However, such is the flexibility of the concept that a 'stand-alone' DPSIR was developed to consider the irrigation system in the Nile Delta region. This analysis was based on a review of literature, previous irrigation reports and interviews with farmers and irrigation experts (Chapter 6).

In summary, the DPSIR framework facilitated the investigation of the main factors that affect land-use change over time in the two study areas. However, the model's conclusions are only as robust as the data used are reliable. The issue of data reliability and availability will be discussed in the next section.

11.3 Evaluation of data used in this study

As mentioned earlier in this chapter, the DPSIR framework dealt with all the various types of data used in this investigation to assess the influence of factors that affect land-use change. Both primary and secondary data were included in the analysis. Primary data collected comprised information from remote sensing image analysis, the questionnaire (economic, social and cultural data), interviews and participant observation. Secondary data included population census figures and agricultural census data (rice area, production, yield and prices). In order to test the ability of the DPSIR framework to deal with these different types of data sources in this study, an evaluation of each type will be presented next.

In this section, the discussion will focus on the extent in which each type of data used in this study has facilitated the analysis. The limitations of each type of these data also will be discussed. Table 11.1 evaluates qualitatively the five types of data used in this study to achieve the aims of the study.

Domain	*Sub-domain*	*Source of data*	*Evaluation & comments*
Driving forces	Physical	Questionnaire, interviews & participant observation	Very good except in determining quantity data for irrigation water
	Economic	Questionnaire, interviews & participant observation	Excellent
	Social and cultural	Remote sensing, questionnaire, interviews, participant observation and census data	Excellent
Pressures	Soil salinisation	Remote sensing, questionnaire, interviews and participant observation	Good
	Desertification		
State	Natural resources	Remote sensing, questionnaire interviews, participant observation	Good
	Crop patterns		
Impacts	Economic performance	Questionnaire & interviews	Good
Responses	Farmer's attitudes	Questionnaire, interviews, participant observation & census data	Good but census data were available at regional scale only
	Technology and skills		
	Governmental policy change		

Table 11.1: Evaluation of data used in this study with regard to the DPSIR framework

11.3.1 Remote sensing data

Data obtained from the analysis of three satellite images, as discussed in Chapters 4, 6 and 7, were used to provide evidence of the encroachment of urban settlements onto agricultural land, crop pattern changes over time (1984-2003) and loss of farmland due to desertification. Calculation of the change in area of urban settlements was straightforward and accurate (Table 11.1). However, there were some limitations in using this type of data for other types of land-use change. For example, the availability of data at different times of the year (August 1984, November 1992 and August 2003) has constrained the comparison because of seasonal differences. To reduce this problem caused by seasonality, analysis of the images to determine the area of crop types was restricted to August alone; 1984 and 2003. Another limitation of using remote sensing data was the small size of crop fields in the research region. To overcome this problem, field visits for farms were made for ground-truthing and interviews with farmers and expert people were conducted to ensure accurate land-use information.

11.3.2 Questionnaire data

A questionnaire survey was used in this study to obtain data about economic, social and cultural indicators for inclusion in the DPSIR framework. These data formed the basis for the statistical analysis conducted in Chapters 6-10. One of the strengths of using the questionnaire in this study was the comprehensive nature of the questions included in the survey. It can be noted from Table 11.1 that questionnaire data were included in the analysis of the five components of the DPSIR framework. The table also shows that using the questionnaire was successful in obtaining detailed data about all the indicators included in land-use change analysis. The data were cross-checked with other information to assess reliability. Twenty of the 120 interviews conducted in Alzaqazig had to be discarded because of internal inaccuracy, whereas 40 of the 120 conducted in Almansourah could not be used. The higher proportion of questionnaires which could not be included in the latter may be due to the farmers' greater sophistication. Indeed, many of the farmers were concerned that the survey was going to be used for tax reasons and were more reluctant to be surveyed. However, the large number of overall respondents ensured that the questionnaire results were representative.

11.3.3 Interviews

The investigation used two types of interviews. First, interviews with farmers from the two study areas and, second, interviews with local expert people in different fields. Information obtained through interviewing farmers were used in the investigation of driving forces, pressures, state of land-use, impacts and responses throughout Chapters 4-10. Data and information obtained through interviewing local expert people were used to investigate two key indicators: the need for irrigation water as a driving force and soil salinity as a pressure indicator. The DPSIR framework was able to incorporate data from different sources (local expert people and farmers) and present a robust conclusion assessing the relative contribution of these factors in determining land-use change in the two study areas. An apparent example that can be presented in this context is the need for irrigation water. The data obtained through the questionnaire with regard to the need for irrigation water in the study areas were very limited. For that reason, using other sources of data (personal comments and farmers interviews) in the context of the DPSIR framework was successful in achieving the aim of assessing the contribution of these factors in land-use change.

11.3.4 Participant observation

Information obtained through participant observation was used to cross-check and triangulate data obtained through questionnaires and interviews, and to further validate the remote sensing data. The DPSIR framework was able to incorporate information and data obtained through participant observation. Table 11.1 shows that participant observation data were used in the analysis and explanation of four components of the DPSIR framework: driving forces, pressures, state of land-use and responses. Indicators that have used participant observation in the analysis of land-use change are shown in Table 3.5. There were seven indicators from different components of the DPSIR framework that used participant observation in the analysis: the need for irrigation water, rural women's contribution in agriculture, area affected by salinisation, type of crop planted in rural areas, irrigation system adopted, agricultural policy changes and settlement of reclaimed areas.

11.3.5 Census data

Government statistics were used in several ways in this land-use change investigation, as discussed in Chapters 4 and 6. The first type was the population census data and the second was the agricultural census data. Population census data were available for each governate rather than each study area alone, but this did not present any particular problems determining the rate of growth. Such uncertainty can easily be handled with the DPSIR framework. Similarly the agricultural census data were for governates rather than each study area and again the explanation and discussion of the agricultural policy was straightforward in the context of the DPSIR framework.

11.4 Conclusions

This chapter has presented an evaluation and critique of the DPSIR framework and data sources used in this thesis. It started with the criteria that should be included in order to decide whether this model has been successful in understanding land-use change in the research region. Section 11.2 discussed the strengths and challenges of the application of the DPSIR framework in this study. Four key strengths were identified in the application of the DPSIR model in this thesis. The discussion has shown that this model was comprehensive, flexible, able to deal with uncertainty and able to exploit different types of information and data resources. In Section 11.3, the discussion focused on the evaluation and limitations of the five sources of data used in this study: remote sensing data, questionnaire data, interviews, participant observation and census data.

Having examined the strengths and limitations of both the DPSIR model and the data used in this study of factors affecting land-use in the Nile Delta, the final chapter will highlight the main conclusions of this thesis and discuss possible options for future work.

Chapter 12: Conclusions and future work

12.1 Introduction

This chapter will summarise the key findings of the research detailed in this thesis. The study aimed to gain a better understanding of agricultural land-use change in the rural-urban fringe in the eastern part of the Nile Delta, Egypt. To address the aim of the thesis, the investigation had the following objectives:

1. To analyse patterns of land-use change in the eastern part of the Nile Delta over the past two decades using remote sensing information and other land-use data.
2. To investigate the importance of the different components of the DPSIR framework (driving forces, pressures, state, impacts and responses) for explaining the observed land-use change.
3. To research the inter-relationships of components of the DPSIR framework for studying land-use change in the eastern part of the Nile Delta
4. To evaluate and critique the application of DPSIR as a conceptual framework to analyse land-use change in the rural-urban fringe of arid areas.

The structure of this chapter will follow the same order as the objectives above. Section 12.2 will summarise the key changes in land-use patterns in the two study areas. In Section 12.3 the discussion will focus on the importance of the main factors influencing land-use change at micro and macro scales. Section 12.4 will summarise the benefits and limitations of the DPSIR model in understanding land-use change in the rural-urban fringe of arid areas more generally. Recommendations for future work will be presented in Section 12.5. The key contributions made by this thesis to existing land-use change debates will be highlighted throughout the chapter.

12.2 Changing patterns of land-use in the study areas

Most of the discussion regarding land-use patterns focused on two distinctly different areas in the eastern part of the Nile Delta, namely Almansourah and Alzaqazig (Chapters 4 and 8). Almansourah is a prosperous ancient settlement with a large university. It is situated relatively close to the Damietta branch of the Nile so that irrigation water is plentiful. In contrast, much of the area adjacent to Alzaqazig was reclaimed fairly recently from the desert and is located at the farthest end of a canal distribution system.

Using remote sensing data it was found that crop patterns had changed considerably in the two areas, both with regard to their geographical distribution and extent. In the Almansourah study area, the key changes during the past two decades were the increase of cotton area and the decrease in rice, maize and other crops. In contrast, the Alzaqazig study area experienced an increase in cotton and rice area with a minor increase in maize fields. There was also an expansion of urban and rural-urban settlements into agricultural land in both the study areas. The main reasons for changes in land-use in the Almansourah study area from the farmers' point-of-view were: lack of alternative employment, market prices, the ending of agricultural subsidies, and making the best use of the fertile soil conditions. Conversely, in Alzaqazig, the reasons for change were found to be soil degradation, lack of employment plus declining market prices and government agricultural policy.

12.3 Importance of factors affecting land-use change

As discussed in Section 2.5, different models and frameworks of land-use change investigation have tried to deal with the interactions between socio-economic and biophysical driving forces at different spatial and temporal scales (Turner II *et al.*, 1995; Verburg *et al.*, 1999; Campbell *et al.*, 2003). In this thesis, the DPSIR framework (driving forces, pressures, state of land-use, impacts and responses) was adopted to investigate the changes in land-use in two contrasting areas in the eastern part of the Nile Delta. Justification for adopting this framework included the flexibility of the approach to analyse complicated linkages (see Sections 1.2, 2.5 and 3.5). The importance of the different components was analysed at two scales; a great level of detail in the two study areas (the micro scale; Chapters 6-9) and at a more general level in the research region (the macro scale; Chapter 10). The study was based in large part on interviews and case studies concerning the experiences of 180 farmers. It should be emphasised that all the farms were owned by men and that not one woman was found to have the sole responsibility for running a farm. At the macro scale interviews were conducted with agricultural experts, and census data were also consulted.

Driving force indicators were considered to be the most important component of the DPSIR framework because, although the model is cyclical and dynamic (Figure 3.5), they can be considered to represent a useful starting point in the land-use change system. For this reason, further consideration will be given here to these indicators. Three key sub-domains of driving forces were identified: physical, economic as well as social and cultural drivers. These driving forces were also found to be crucial by many other studies that investigated land-use change in different regions (Serneels and Lambin, 2001; Geist and Lambin, 2002; Wood *et al.*, 2004; Mottet *et al.*, 2006). One of the critical physical indicators for land-use change was found to be the need for irrigation water (see also Little *et al.*, 2001). Regarding the two study areas, Almansourah currently enjoys greater availability of irrigation water because of its proximity to the Nile (compared to Alzaqazig) which facilitated land-use change in Almansourah. On a more general level, the aridity of the Nile Delta region makes water a limiting factor in agricultural production. Government policies with regard to irrigation water clearly have a major effect on land-use change. Already the government is reducing the amount of water available to farmers in the region in order to save it for the giant projects in Toshka and the Sinai Peninsula. Therefore, farms which are situated near to a distribution canal with a reliable flow will always have an advantage over more remote ones when resources are scarce. Land-use change, therefore, was particularly sensitive to irrigation water shortage.

Before discussing the importance of the economic and social drivers, the two environmental pressures associated with the availability or lack of water, desertification and soil salinisation, will be considered. Desertification was a key feature of land-use change in Alzaqazig. This result was due to its geographical location adjacent to the Egyptian Eastern Desert. The high level of soil salinity, associated with irrigation and poor drainage, led to farmers in the area changing their crops to more salt tolerant ones such as rice. Very few farmers in Almansourah (5%) reported that they had changed crops due to either desertification or salinisation. Regions, therefore, which have been cultivated for a long time, and where the soils have built up high levels of fertility, are buffered to some extent against these two environmental pressures (FAO, 1994; Rowell, 1994; Brady and Weil, 2000; Patiram *et al.*, 2003).

Economic drivers of land-use change were investigated to find out which, if any, were key drivers. Government subsidies were examined to assess the importance of this agricultural policy as a driver for land-use change. However, statistical analysis found no significant link between such subsidies and land-use change in either of the study areas. This result was explained by changes in agricultural policy in 1986 and 1993. Until 1986, the role of agricultural policy in land-use change was crucial because the government controlled the area, production and prices of the major crops including cotton, wheat, rice, and sugar cane. The influence of agricultural subsidies decreased gradually during the period 1986 to 1993 when government subsidies were eliminated completely and the private sector started to provide subsidies to farmers. The resultant change in land-use was a response to the changing policies and in line with other studies which emphasised the role of agricultural policy as a key driver for land-use change (Mattison and Norris, 2005; Wilson and Juntti, 2005; Rounsevell *et al.*, 2006).

The role of private source subsidies in land-use change was also examined; this indicator played a significant role in Alzaqazig but not Almansourah. Farmers in Alazaqazig with fewer resources desperately needed to subsidise their agricultural production from private sources unlike those in the long settled area of Almansourah. These results were supported by many other studies from different parts of the world (Barbier, 1997; Matson *et al.*, 2005; Lambin and Geist, 2006). Lambin and Geist (2006) for example emphasised that agricultural subsidy is playing a crucial role in affecting land-use change in both developed and developing countries. They argued that "*in particular, taxes and subsidies are important driving forces of land-use dynamics and related land cover and ecosystem changes. Currently, many subsidies substantially increase rates of resource consumption and negative externalities*" (Lambin and Geist, 2006: 47). It is, therefore, important to stress that any study of land-use change in developing countries must take into account the role of subsidies as one of the driving forces.

Two more economic indicators were analysed in connection with land-use change in the two study areas: transportation availability and transportation cost as a percentage of total agricultural cost. Statistical analysis showed that land-use change was significantly influenced by transportation availability and costs in Almansourah but not in Alzaqazig. The distinction between the two areas was explained by the greater wealth and higher standard of living farmers enjoy in Almansourah compared with Alzaqazig as more of the produce in Almansourah was transported and sold at market. The importance of transportation cost in affecting land-use change was highlighted by many other studies (Clark, 1967; Rasul *et al.*, Robinson, 2004; Crosier, 2006). Crosier (2006) for example argued that Von Thunen's model in 1826 suggested that profits at the central market depends not only on the market value of the product but also on the transportation costs to get the product to the market. This theory may therefore offer an explanation for contemporary land-use patterns in villages and farms in some developing countries; the results of the present study confirmed that transportation cost is still fundamental in determining patterns of land-use in the research region where markets play a vital role in the economy (Section 10.9). It is important, therefore, to consider the availability and cost of transportation when investigating land-use change at the local level.

Three social and cultural drivers were found to influence land-use change to different degrees in the two study areas: population growth, farmers' educational levels and rural women's contribution in agriculture. Evidence from remote sensing images and population census data showed that population growth in Almansourah had a greater impact on land-use than in Alzaqazig. The pressure for building on agricultural land in Alzaqazig was reduced because of the availability of extensive areas of reclaimed desert adjacent to the city. In contrast, the lack of alternative sources of land in Almansourah led to the expansion of urban and rural urban settlements onto valuable agricultural fields. These results were supported by other studies from different regions around the world (Gar-on Yeh and Li, 1999; Laurance *et al.*, 2002). It can be concluded from this study that population growth is a very critical driver affecting land-use change in peri-urban areas.

Farmers' educational levels were investigated because it was hypothesised that education was a critical indicator in determining the farming practices in the two study areas (Section 2.6). A farmers' educational level significantly influenced agricultural rotation and manure recycling only in Almansourah. Conversely, the level of education was only linked with family role in agricultural production in Alzaqazig. These results were in line with other studies which suggested that farmers' education is important to accelerate agricultural production (FAO, 1996; Feder *et al.*, 2003). Women's contribution to agricultural production affected land-use change to some extent in Alzaqazig but not in Almansourah. The contribution of rural women to agricultural production was investigated by many other authors (Kaur and Sharma, 1991; Rahman, 2000, Robinson, 2004; Al-Rousan, 2005). The results of this study were supported by Turner (1999). He argued that gender relations in rural Africa, while shown in local studies to play an important role in land-use change, are often excluded from consideration in regional analyses. Indeed, their contribution often does not appear in formal statistics. However, it is important to emphasise the crucial role which women play in agriculture and land-use change.

The role of driving force and response indicators in influencing land-use change was aggregated at the research region level in Chapter 10. As a result, the ranking hierarchy showed that transportation cost as a percentage of the total agricultural cost is a fundamental explanation of land-use change in the research region, followed by subsidies from private sources, farmers' educational levels and finally rural women's contribution in agriculture. The relative ranking of driving force and response indicators affecting land-use change in the research region is: transportation cost > private source subsidies > farmers' educational levels > rural women's contribution in agriculture.

In summary, the availability or lack of water was found to be a paramount driver and the associated pressures of desertification and salinisation particularly influenced land-use change in areas adjacent to the desert. Economic factors were observed to play a greater role in land-use change than the social and cultural ones (see also Alig *et al.*, 1988; Xu *et al.*, 2002). Transportation cost was more important than either level of education or the involvement of women. The role of distance from the market in terms of land-use change, as highlighted by Von Thunen in the nineteenth century, was still found to be fundamental for the more market orientated city of Almansourah but not for the more peripheral area of Alzaqazig. While investment in better transport links can be shown to pay dividends for agriculture, investment in education could play a greater role in securing a sustainable long-term future for the region. These findings are also echoed by other studies from different parts of developing countries (Lockheed *et al.*, 1980; Pudasaini, 1983; Phillips, 1994).

12.4 Evaluation and critique of the application of the DPSIR framework in this study

One of the main aims of this thesis was to determine whether the DPSIR framework could be successfully applied to the study of land-use change in a semi-arid region with a history of autocratic government. This section will summarise the discussion in Chapter 11 regarding the advantages and limitations of the DPSIR framework with regard to its application in this thesis. The model was found to be robust in organising and categorising the various indicators which were assumed to influence land-use change at the level of the study region and study areas. It was also able to answer "what if" questions. The nature of the casual links between the five components (driving forces, pressures, state of land-use, impacts and responses) enabled this framework to track changes of consequences once the causes change. The ability of this framework to include different types of indicators (physical, economic, social and cultural) makes it a comprehensive model. This result was supported by many authors (Du Plessis, 2003; Giupponi *et al.*, 2004; Kristensen, 2004; Wei et al., 2005). Du Plessis (2003) for example argued that "*The DPSIR framework provided an adequate model for mapping the various relationships between the current state of human settlements in South Africa, their environmental and socio-economic impact, the drivers and pressures that caused the impacts, the responses to these and their contribution to further pressures*" (Du Plessis, 2003: 9). The discussion in Chapter 11 highlighted the flexibility of the DPSIR framework and demonstrated that it was able to focus on the most relevant indicators and ignore others (Antunes and Santos, 1999; Walmsley, 2002).

A major strength of the DPSIR framework was the ability to deal with different types of data and information resources: remote sensing data; questionnaire data; interview information; participant observation and population and agricultural census data. A further strength was the capability to deal with uncertainty (Brouwer *et al.*, 2003) as it has the capacity to include sub-models where appropriate to explain observed patterns at both the macro scale and micro scale (e.g. Chi square model, Probit analysis model).

Before discussing the limitations of the DPSIR framework applied in this thesis, it is important to emphasise that one of the objectives of this research was to explore the drivers of land-use change in the Nile Delta and to look at the 'big picture' in terms of significant variations in space and time. This was because there have been relatively few previous studies of land-use or land-use change in Egypt. It was vital therefore to capture an overview of what was happening on the ground and to achieve this task quantitative information such as remote sensing data and census data were used because they were readily available. Such information usually cover large areas; Landsat 'scenes' cover around 10000km^2 and census data are available at the scale of a governate. The challenge for this study was to use such data and determine whether the DPSIR approach could be used in dissimilar social, economic and political situations from that in which it was developed.

One result of this study was that the DPSIR framework can work well in a more extreme environment such as found in the Nile Delta. Part of the reason why it could be applied successfully was that, at the scale of enquiry, there were considerable social, political and economic changes through time and there were also considerable contrasts within the region. Examples of such diversity included:

Policy changes; 'centralised decision making' to 'free market'

Physical resources; fertile soil to inert sand

Water availability; abundant to lack

Population; substantial rate of growth

Education: from illiterate to college educated farmers

Transport: poor access to excellent availability

The comparisons of the drivers of land-use change between Almansourah and Alzaqazig worked well because of the considerable contrasts between them. One point to note is that the DPSIR approach is by nature 'reductionist' and provides a framework for exploring processes of change in ever greater depth within selected areas. However, in order to analyse a large enough sample for statistical analysis it was necessary to aggregate data to carry out the PROBIT analysis successfully (Section 10.9). Such an approach, whilst it produced significant results, however, was not ideal.

There were a number of advantages of adopting the DPSIR framework for this study especially in the way that it could incorporate both quantitative and qualitative data; information from interviews, for example, was used to complement the analysis of quantitative land-use change data. However, various limitations were also noted, in part due to the conceptual framework itself, and partly because of the scale of interest at which the method can be successfully applied.

A number of limitations of the DPSIR framework were identified in this study; for example the approach cannot really deal with analysing subtle patterns of land-use change and does not have the capability to reflect the authentic voices of individual farmers. First, the problem of treating land-use change as a single event was recognized. Although the DPSIR framework was able to capture the interrelationships between causes of land-use change and other components (pressures, state, impacts and responses) at the large scale, its mono-dimensional and linear relationships have constrained the investigation of land-use change and ignored the more multi-dimensional and complex nature of temporal change. This shortcoming of the DPSIR framework has been noted as one of its most serious limitations (Dhakal, 2002; and Vacik *et al.*, 2005).

Second, the problem of multi-causality and the inadequate way that the DPSIR framework can determine the exact causes of subtle change was identified in this study (Smeets and Weterings, 1999; Bosch, 2002). In an attempt to capture some aspects of multi-causality, the study has utilised three sub-models of the DPSIR framework (Chapter 5). The first sub-model was designed to explain the interrelationships between physical driving forces and pressures, state of land, impacts and responses. It was used to comprehend the processes in which the physical drivers such as the need for irrigation water, use of fertilisers and use of agricultural pesticides have affected changes in land-use. The second sub-model was used to understand how the economic driving forces such as agricultural subsidies and transportation availability and cost are affecting land-use changes in a multi-causal way and relate the impacts of these changes to the relevant origins. The third sub-model was utilised in the same way described above to capture the multi-causality of social and cultural driving forces such as population growth, farmers' educational levels and rural women's contribution in agricultural production (Chapter 5).

Third, the exact classification of some indicators within the framework (e.g. agricultural policy as a driver or a response) was difficult. For many factors it was straightforward to decide which category they were in. For example, by definition drivers consist of the needs of individual and institutions that lead to activities that put pressures on the agricultural production and land-use. A farmer's aspirations and behaviour can only be allocated to the driving force component. However, some indicators, as mentioned in Chapter 3, were more ambiguous to classify. For example, the change in agricultural policy was considered as a response to reduce an increasing pressure in this study, even though it could be argued that it is also a driving force component as one of the causes of land-use change (Wilson and Juntti, 2005). This issue of ambiguous classification was noted in by the UK Ministry of Agriculture, Fisheries and Food (MAFF, 2000) who stated that "*It can also be difficult to decide whether a particular environmental feature or trend is a driver, state or response. A response can become a driver (e.g. agri-environment schemes introduced as a response could become drivers) and a pressure could be viewed as a state*".

The fourth challenge encountered in the application of the DPSIR framework in this thesis was the lack of available data required for analysing crucial indicators (e.g. quantity of irrigation water). The difficulty in obtaining any data about the operation of the irrigation system at the farm scale and particularly the quantity of irrigation water and its scheduling meant that this important indicator had to be omitted from the main DPSIR framework. However, such is the flexibility of the concept that a 'stand-alone' DPSIR was developed to consider the irrigation system in the Nile Delta region. This analysis was based on a review of literature, previous irrigation reports and interviews with farmers and irrigation experts.

On balance, at the scale of this land-use change investigation in the Nile Delta, the strengths of the DPSIR framework outweighed the disadvantages. Although it was developed in Europe, it appears to work well in a contrasting socio-economic and political setting; the method of analysis was pertinent in such a more centralised government setting. Clearly an understanding of the political and environmental background of a given area is crucial to the way in which the DPSIR framework is applied.

The DPSIR framework can be applied successfully at the large scale where changes in land-use and their driving forces, pressures, state of land, impacts and responses need to be clarified prior to a more in depth investigation of more subtle, nuanced spatial and temporal changes. One of the main contributions to knowledge of this thesis is the importance of the empirical contribution of the DPSIR framework to land-use change studies practically in arid and semi-arid areas of the developing countries. This conclusion was in line with the land-use change workshop at Adana, Turkey which concluded that "*the overall agreement was that the DPSIR framework is accepted by the partners as a good tool and will be used extensively during the lifetime of the project, especially for developing policy guidelines for national and regional development*" (Zdruli et al., 2003: 8).

In summary, one of the main lessons learned about the DPSIR framework and its application to land-use studies was that it can be applied most successfully at the large geographical scale where there is good availability of quantitative data and there are clear trends through time. The approach offers a robust, comprehensive way of organising complicated data to focus on the main drivers affecting change. In situations where changes are more subtle, and the spatial and temporal scales are more limited, DPSIR does not cope very well with small distinctions. Section 12.5 will consider future work with regard to the application of the DPSIR framework in different physical, economic and social settings.

12.5 Future work

As explained in the research methodology (Section 3.2.3), I have considerable experience of agriculture in Syria and am employed as a lecturer in the Faculty of Agriculture at Damascus University. To take my research forward I wish to contribute to an understanding of sustainable land-use patterns in Syria and to the growing debate regarding land-use change in general. Building on experience gathered through this thesis, patterns of land-use change will be identified using agricultural census data and analysed using the DPSIR framework. The key drivers affecting land-use change in a small region of Syria will be identified and their role compared to those discerned for the Nile Delta region.

Given the strengths of the DPSIR framework as demonstrated in this study, further investigation with regard to the application of this model in Syria is fundamental to understand land-use change in a more centralised government with different physical, economic as well as social and cultural driving forces. A crucial element will be, therefore, to test whether DPSIR will work in Syria and whether it can facilitate the investigation of driving forces, pressures, state of land-use, impacts and responses.

A number of lessons were learned regarding the evaluation and critique of the DPSIR framework and various sources of data and information from this thesis that can be applied in future work. One of the most important lessons that will be reflected in my future study is the emphasis on the empirical contribution of the DPSIR framework in land-use change studies. This means that in addition to utilising most of the advantages of the DPSIR model mentioned above, the limitations will be recognised at an early stage and the framework will be adapted to take them into account. Although some of the critique points are unavoidable (e.g. mono-causality nature of the DPSIR framework), others can be dealt with (e.g. the exact classification of driving forces and responses, some data availability). As a result, taking into consideration the political ecological setting of the area under investigation and the weakness points of the DPSIR model before the application will lead to understand better the causes and impacts of land-use change in any future study.

An important lesson learned during the study was that interviews with farmers yielded extremely valuable data about the various indicators influencing land-use change. Following analysis of the data, the next step is to apply the information to promote agricultural production in rural areas of Syria. This study has shown that there is a need to focus research on key factors such as transport, subsidies, education and the role of women. The applied nature of such research work is vital in a developing country and recommendations to policy makers and extension officers should result in a more sustainable land-use system in Syria.

Appendix I

A questionnaire designed for investigating land-use change in the Nile Delta, Egypt

Author: *Rawad S. Echtaie* *date…………*

Study area: *(1) Alzaqazig……….* *(2) Almansourah…………*

***Farmer respondent** ……..*

I would be grateful if you could give me the time to answer these questions:

Q1- how old are you?

A1- …………………………………… years old

Q2- do you work here as

a- an owner……………. **b-** a tenant………… **c-** other (please specify) ……….

Q3- how many years did you spend at schools or colleges?

A3- ……………………… Year

Q4- have you received any informal educational (other than your schools education?

a- yes ………. **b-** no……….

Q5- how long have you been living in this town?

A5- ……………………… years

Q6- could you please tell me your farmland size?

a- less than 5 feddan……… **b-** between 5 and 10 feddan……….

c- 10-20 feddan………. **d-** 20 feddan or more………………

Q7- what types of crops do you plant usually at your farm?

a- In winter: 1- .... 2-............................. 3-...........
4-.................... 5- .... 6-...........

b- In summer: 1-.................... 2-............................... 3-...........
4-.................... 5-............................... 6-...........

Q8- during the last 20 years, did you change the type pf crop you plant?

a- yes.......... b- no..........

Q9- if you answered yes, what were the reasons for that change?

a- climate condition....... b- market's prices...........

c- Government's agricultural policy.........

d- soil condition......... e- others (............................)

Q10- what kind and numbers of livestock do you breed in your farm?

a- ....( ) b-..........( ) c-..........( ) d- ....( )

Q11- do you follow the crop rotation plan recommended by the government?

a- always............. b-Sometimes............. c- Never...........

Q12- did you get or do you get any subsidies from any governmental source?

a- yes I did but not any more......... b- I am having at the moment..........

c- never .... d- if I get the chance I will...............

Q13- did you or do you get any loans from any private banks?

a- yes I did but not any more......... b- I am having at the moment.........

c- never .... d- if I get the chance I will...........

Q14- what type of irrigation system do you use at your farm?

a- conventional (flooded)........... b- trickle ....

c- Spray........... d- other (please specify) ....

Q15- As an average, how many cubic meters of agricultural water do you consume per year?

A13- .... m^3

Q16- do you use any kind of fertilisers in your crop production at your farm?

a- yes.......... b- no...........

Q17- if yes, please specify kind and amount each of them

a- Nitrogen .... kg\feddan b- potassium .... kg\feddan

c- Phosphate .... kg\feddan d- others (please specify) ......kg\feddan

Q18- do you use any kind of pesticides in you crop and\or livestock production at your farm?

a- yes ...... b- no........

Q19- if yes, please specify kind and amount each of them

a- seed's pesticide...... kg\feddan b- insect's pesticide....... kg\feddan

c- Disease pesticide.........kg\feddan d- herbicide ....kg\feddan

Q20- in your farming production and marketing, do you have your own motor vehicle, or you use the public transport services?

a- I have my own vehicle........ b- I use public transport services......

Q21- how much as a percentage of total farm works cost do you spend on farming transportation?

a-less than 5%........... b-between 5 and 10%.........

c-10-20%......... d-more than 20%.............

Q22- how do you get rid of the farm manure?

a- In a canal or the Nile........... b- Plough them into the soil..........

c- In the desert area......... d- others (please specify) ....

Q23- how much as a percentage of total costs do you spend on reducing soil degradation?

a- nothing........ b- 5 -10%........... c-10-15%..........d-more than 15%.......

Q24- does your family contribute to the farm work?

a- yes....... b- no......

Q25- if yes, how many of the family members taking part in the farm work are males\females?

males	age	females	age
1-		1-	
2-		2-	
3-		3-	
4-		4-	
5-		5-	

Q26- during the last 20 years, did you lose any agricultural land due to desertification in the area?

a- yes I lost.......... b- No I did not.............

Q27- due to land reclamation, did you gain any agricultural land during the last 20 years?

a- yes I did .... b-no I did not.........

Q28- did you or do you receive any agricultural extension from the experts in your area?

a- no I did not.......... b- Yes I did but not any more ....

c- I did not but I do nowadays......

Q29 - If yes, how often was that?

a- always .... b-not very often....... c- rarely.........

Q30- did you receive any kind of training or new skills related to farm management practices?

a- yes I did .... b- no I did not.......

Q31- If yes, what were they about?

a- irrigation system........ b- crop production procedures......

c- Livestock husbandry.......... d- Finance and marketing..........

Q32- do you receive guidance from any governmental agents as regards social or family planning affairs?

a- yes I do........ b- no I do not........

Appendix II

List of acronyms

AVHRR	Advanced Very High Resolution Radiometer
CD	Central Directorate
CLUE	Conversion of Land-Use and its Effects
DPSIR	Driving forces, pressures, state, Impacts and Responses
DRI	Drainage Research Institute
EEA	European Environment Agency
ER	Effective Rate
ETM	Enhanced Thematic Mapper
EPADP	Egyptian Public Authority for Drainage Projects
ERSAP	Economic Reform and Structural Adjustment Programme
FAO	Food and Agriculture Organisation
GD	General Directorate of Irrigation
GDP	Gross Domestic Product
GIS	Geographical Information Systems
GLP	Global Land Project
ICID	International Commission on Irrigation and Drainage
IGBP	International Geosphere Biosphere Programme
IGU	International Geographical Union
IHDP	International Human Dimensions Programme
IS	Irrigation Sector
LE	Egyptian Pound
LUCC-MA	Land-Use and Cover Change Millennium Assessment

MEP	Monitoring and Evaluation Project
MOA	Ministry of Agriculture
MPWWR	Ministry of Public Works and Water Resources
MSS	Multi Spectral Scanner
MT	Metric Tonnes
MWRI	Ministry of Water Resources and Irrigation
NDP	National Drainage Programme
NDVI	Normalized Difference Vegetation Index
NIR	Near-Infrared
OECD	Organisation for Economic Co-operation and Development
PBDAC	Principal Bank for Development and Agricultural Credit
PSR	Pressure, State and Response
SPSS	Statistical Package for the Social Sciences
TM	Thematic Mapper
TNCs	Transnational Corporations
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNSO	United Nations Sudano-Sahelian Office
WCU	Water Communications Unit
WTO	World Trade Organisation

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